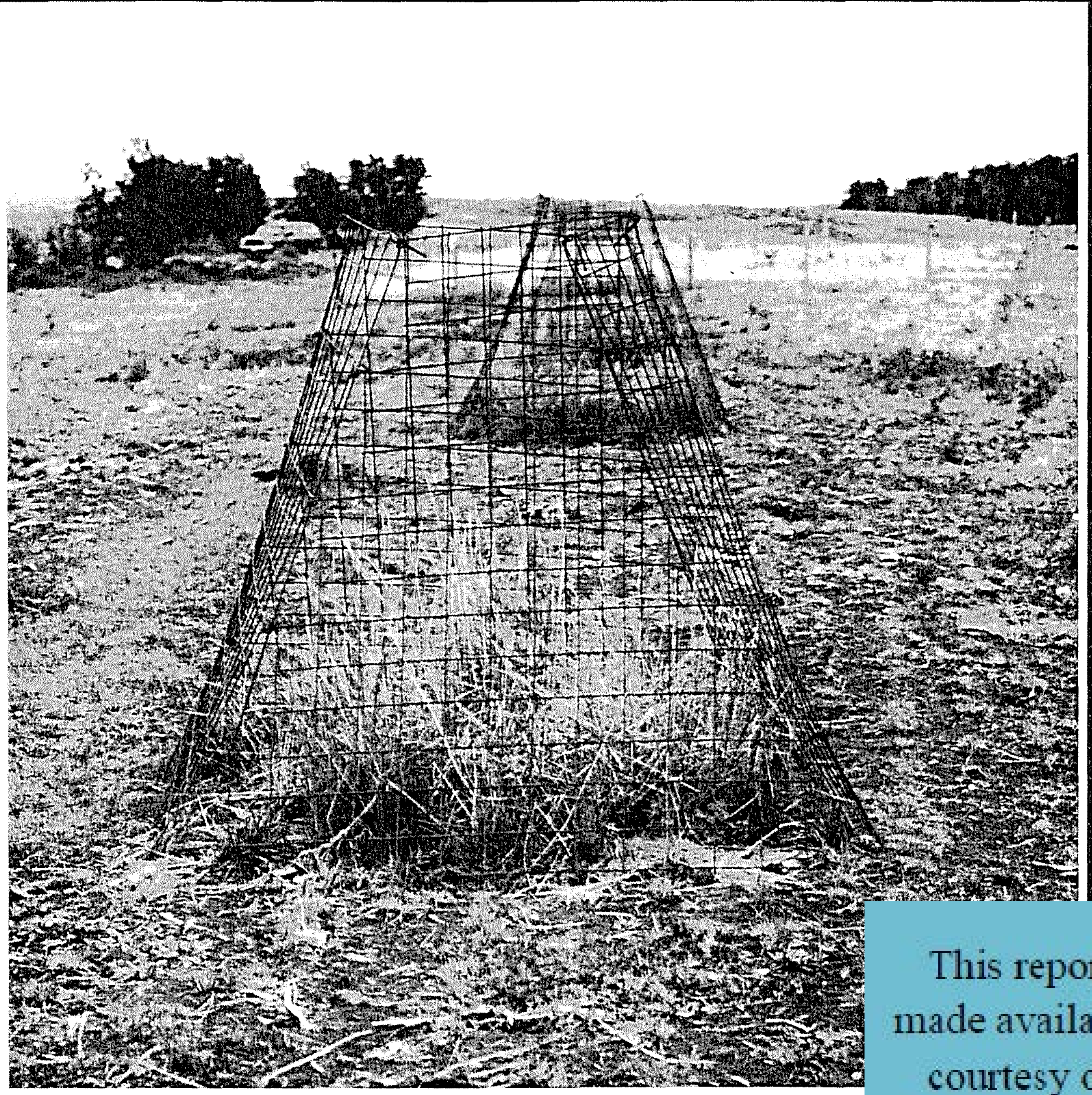
RANGELAND REVEGETATION MONITORING ON TWO PIPELINE RIGHTS-OF-WAY IN SOUTHERN ALBERTA



NOVA Gas Transmission

RANGELAND REVEGETATION MONITORING

ON TWO

PIPELINE RIGHTS-OF-WAY

IN

SOUTHERN ALBERTA

by

M. A. Naeth,
A. T. Lees,
J. Bietz,
B. D. Irving
and
A. W. Fedkenheuer

Environmental Research Monograph 1997-2

NOVA Gas Transmission Ltd.
Community Resources
Calgary, Alberta

1997

FOREWORD

NOVA Corporation (NOVA) is a major Canadian energy company involved in pipelining and the manufacturing and marketing of produced petrochemicals. NOVA Gas Transmission Ltd. (NGTL) of NOVA is concerned with natural gas system design, pipeline construction, research and facility operations throughout the province of Alberta. Since its incorporation in 1954, NGTL has installed more than 21,700 km of natural gas pipeline and continues to operate, maintain, and expand this system.

NGTL Environment Research Monographs are published verbatim from the final reports of professional environmental consultants or company staff. Only proprietary technical or budget-related information is withheld. Since NGTL decisions are not necessarily based on one person's opinion, recommendations found in the text should not be construed as commitments to action by the company.

NGTL welcomes public and scientific interest in its environmental activities. Please address any questions, comments, or requests for reports to:

> ***Manager, Community Resources, NOVA Gas Transmission Ltd., P.O. Box 2535, Postal Station M, Calgary, Alberta, T2P 2N6***

This study was commissioned to assess rangeland revegetation productivity, species composition, and forage utilization by cattle on and off two pipeline rights-of-way in southern Alberta. The report was prepared by M. A. Naeth, University of Alberta, A. T. Lees, NOVA Gas Transmission Ltd., J. Bietz, NOVA Gas Transmission Ltd., B. D. Irving, University of Alberta, and A. W. Fedkenheuer, NOVA Gas Transmission Ltd..
This report may be cited as:

> ***Naeth, M. A., A. T. Lees, J. Bietz, B.D. Irving and A. W. Fedkenheuer. 1997. Rangeland revegetation monitoring on two pipeline rights-of-way in southern Alberta. NGTL Environmental Research Monographs 1997-2. NOVA Gas Transmission Ltd., Calgary, Alberta. 58 pp.***

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Field sites for this study were established in 1987 shortly after the completion of construction of two pipelines in southern Alberta. The Dry Mixed Grass and Mixed Grass Ecoregions (Milo Pipeline Lateral) and the Aspen Parkland, Montane and Fescue Grassland Ecoregions (Porcupine Hills Lateral) were selected for study plots to compare vegetative productivity, plant species composition and animal utilization on the pipeline right-of-way to that of the adjacent native grassland. Field assessments were conducted over four growing seasons.

Grass production decreased, as expected, in the first year after construction, but it then increased, and in the Dry Mixed Grass and Mixed Grass Ecoregions, often exceeded pre-disturbance levels. Grass production was higher on unseeded than seeded areas. Forb production showed an increase in the first year after the disturbance, and generally remained higher on disturbed treatments than on the control over time. Total herbaceous production showed a general increase with time on all disturbed treatments, particularly at the Milo sites, due to the increase in grass production.

Bare ground was not significantly different between the disturbed areas seeded to native species and the adjacent native grasslands, within four years of construction. For areas seeded to non-native species bare ground was still significantly higher in disturbed areas. After four years litter on areas seeded to native species was greater on the pipeline trench than in the adjacent control area. For all disturbed areas seeded with non-native species, litter was greater than for the controls.

A lack of little club moss on study sites in the Dry Mixed Grass and Mixed Grass Ecoregions resulted in less similarity between disturbed and undisturbed sites over time, especially in areas seeded to non-native species. In the Aspen Parkland, Montane and Fescue Grassland Ecoregions, plant species composition became more similar over time between the pipeline right-of-way and the adjacent control.

Grazing did not show a discernible effect on cover. There were strong, but highly variable trends for higher overall forage utilization on the pipeline trench than in undisturbed control areas at all sites.

ACKNOWLEDGEMENTS

The authors acknowledge the financial assistance of NOVA Gas Transmission Ltd. (NGTL) for this project. The assistance of Debra Smith, Dan Axelsson and NGTL's Land team in site selection and establishment is also acknowledged, as is the cooperation of the various landowners or managers where the rangeland exclosures were established. These include: Eugene Cyr, Circle E Grazing Association, Ron Davies, Francis Gardiner, Lomond Grazing Association, Gene Rowland and the Waldron Grazing Association. A thank you also to Tracy Patterson for her efforts in editing and publishing the report.

I. INTRODUCTION

NOVA Gas Transmission Ltd. (NGTL) is an Alberta based company involved in the transportation of natural gas. NGTL operates approximately 21,700 km of pipeline and consequently has an extensive reclamation program. Many of these pipelines are constructed in native grasslands, which can pose problems for successful re-establishment of an acceptable vegetative cover.

Native rangeland is an important resource for both domestic animals and wildlife. A disturbance such as a pipeline right-of-way (RoW) is often seeded with non-native plant species, which can make management of the adjacent native range more difficult. These non-native species often differ from native species in palatability to livestock, so the pipeline changes normal grazing patterns in a given field. Animals tend to preferentially graze non-native species, thereby increasing grazing pressure and limiting reclamation success.

In 1986, NGTL initiated a long-term revegetation monitoring program to assess revegetation efforts on native rangelands in southeastern and southwestern Alberta. The purpose of the rangeland revegetation monitoring program was to:

1. Compare vegetative productivity of the pipeline RoW to that of the adjacent native grassland,
2. Compare plant species composition on the pipeline RoW to that of the adjacent native grassland, and
3. Compare animal utilization of the pipeline RoW to that of the adjacent native grassland.

This report presents the results of vegetation assessments conducted in 1988, 1989, 1990, and 1991.

Numerous individuals were involved in this project. The sampling layout was designed by J. Derosie, A.T. Lees and A.W. Fedkenheuer of NGTL. The soil inventory of the Milo Lateral was conducted by R. McNeil and N. Finlayson and that of the Porcupine Hills Lateral by N. Finlayson. Field vegetation data collection was conducted by Eastern Slopes Rangeland Consultants. M.A. Naeth and B.D. Irving, of the University of Alberta, completed the data analyses and interpretation.

II. STUDY SITE DESCRIPTIONS

The pipelines monitored were the Milo Lateral, located in southeastern Alberta, and the Porcupine Hills Lateral, located in southwestern Alberta (Figure 1).

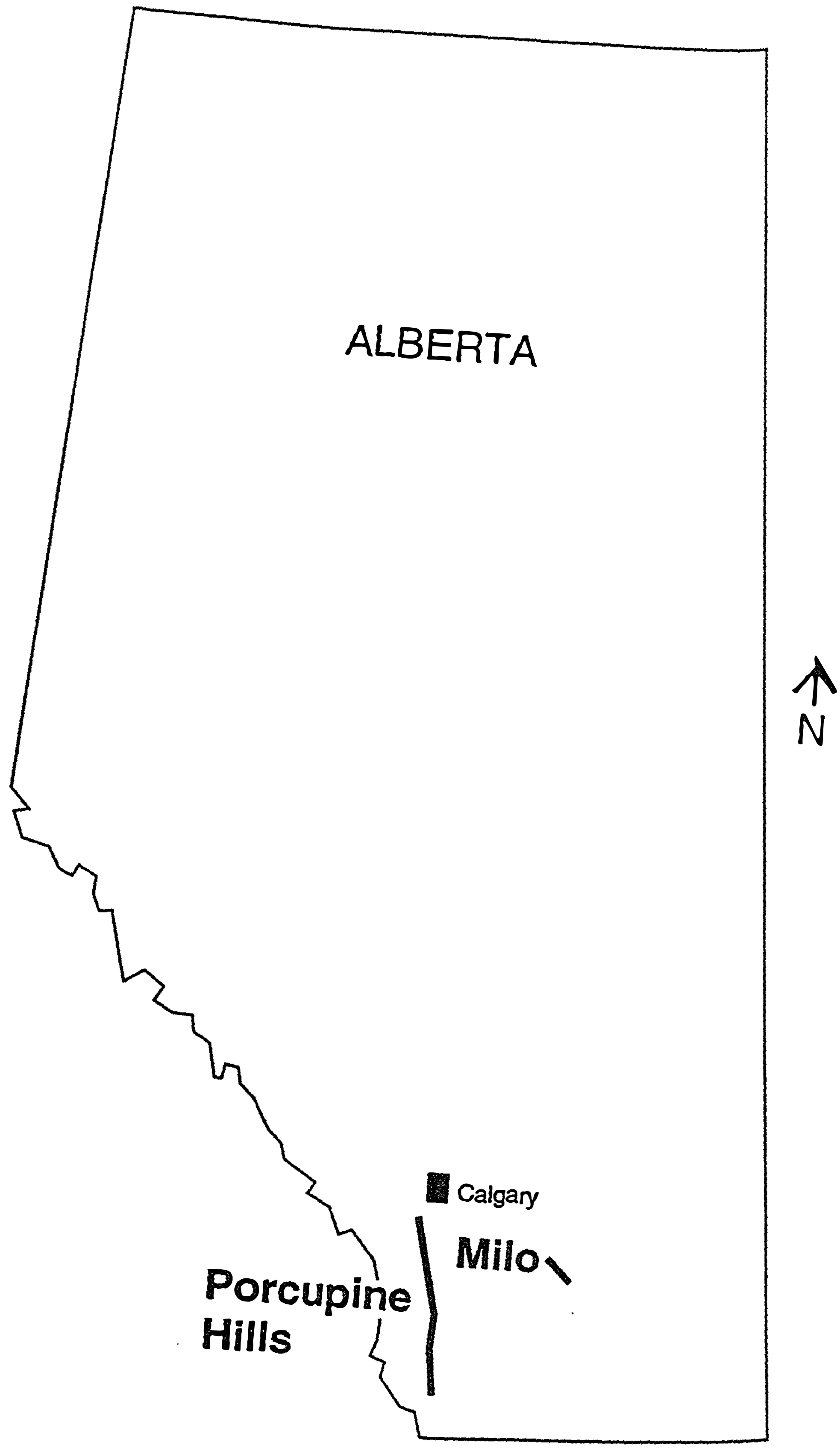


Figure 1. Rangeland revegetation study areas.

A. Milo Lateral

The Milo RoW, 39 km long and 18 m wide, was built in southeastern Alberta in the summer of 1986. This lateral transports sweet natural gas from the Milo Meter Station at SW-31-18-19-W4 to the Badger East Meter Station at NE-13-16-17-W4. Topsoil conservation involved ditchline stripping with the stripped soil stockpiled on the work side of the RoW.

The Milo Lateral traverses the Dry Mixed Grass and Mixed Grass Ecoregions which are characterized by undulating topography, Brown Chernozemic soils and a subxeric soil water regime with the lowest summer precipitation of any ecoregion in Alberta. May through August are the hottest months with a monthly mean of 16.2 °C. These temperatures combined with low precipitation (210 mm $summer^{-1}$, 340 mm yr^{-1}) and strong persistent winds, produce potential evapotranspiration deficits that exceed 100 mm mo^{-1}. There is shallow snow cover and only a few days when snow cover is continuous.

Plant species reflect severe summer moisture deficits (Appendix I A). Dominant species include needle and thread (*Stipa comata*) and porcupine grass (*Stipa curtiseta*), with secondary occurrences of blue grama (*Bouteloua gracilis*). Other common species are little club moss (*Selaginella densa*), pasture sage (*Artemisia frigida*), moss phlox (*Phlox hoodii*) and thread-leaved sedge (*Carex filifolia*).

All four study sites on this lateral are located on property managed by the Lomond and Circle E Grazing Associations.

1. Site One

Legal: NW-23-16-17-W4M
Ecoregion: Dry Mixed Grass
Parent Material: Fine-loamy till
Topography: Very gently to gently undulating
Drainage: Well to moderately well drained
Stoniness: Slightly stony

Vegetation: Dominant species are blue grama (*Bouteloua gracilis*), needle and thread (*Stipa comata*) and little club moss (*Selaginella densa*). June grass (*Koeleria macrantha*), wheatgrasses (*Agropyron spp.*), bluegrasses (*Poa spp.*), sand dropseed (*Sporobolus cryptandrus*), pasture sage (*Artemisia frigida*), moss phlox (*Phlox hoodii*) and sedges (*Carex spp.*) are common.

Soils: Soils at this site are the most variable of the Milo sites, with seven soil map units delineated. Brown Solods dominate with occurrences of Solonetzic Brown Chernozems and Brown and Gleyed Brown Solodized Solonetzes. Soil pH ranges from 6.0 to 9.0. Soil electrical conductivity ranges from 0.14 to 20.10 mS cm^{-1}. Blowouts are common. Soil organic carbon ranges from 0.9 to 2.3% on the trench and 2.1 to 2.5% off the trench.

Grazing History:

1987 .... 316 cattle .... September 5 to October 5
1988 .... 448 cattle .... May 1 to June 7
1989 .... 305 cattle .... June 16 to September 25
1990 .... 1128 AUM .... May 11 to August 20
1991 .... 590 AUM .... August 23 to September 27
1992 .... 618 AUM .... July 1 to 20, August 28 to September 3

2. Site Two

Legal: SE-27-16-17-W4M
Ecoregion: Dry Mixed Grass
Parent Material: Fine-loamy till
Topography: Very gently undulating
Drainage: Well to moderately well drained
Stoniness: Non to slightly stony

Vegetation: Vegetation is similar to Site 1, dominated by blue grama (*Bouteloua gracilis*), needle and thread (*Stipa comata*) and little club moss (*Selaginella densa*) with common occurrences of June grass (*Koeleria macrantha*), wheatgrasses (*Agropyron spp.*), bluegrasses (*Poa spp.*), sand dropseed (*Sporobolus cryptandrus*), pasture sage (*Artemisia frigida*), moss phlox (*Phlox hoodii*) and sedges (*Carex spp.*).

Soils: Five map units have been identified on variations in profile, parent material, slope and drainage. Brown Solods dominate with significant occurrences of Brown Solodized Solonetz and some Solonetzic Brown and Orthic Brown Chernozems. Soil pH, electrical conductivity and organic carbon are similar to the values of Site 1.

Grazing History:

1987 .... 74 cattle .... May 1 to July 9
1988 .... 153 cattle .... May 1 to August 20
1989 .... 89 cattle .... May 1 to June 16
1990 .... 547 AUM .... June 9 to July 26
1991 133 AUM .... June 24 to July 2
1992 .... 166 AUM .... June 24 to July 1

3. Site Three

Legal: NW-14-18-19-W4M
Ecoregion: Mixed Grass
Parent Material: Coarse loamy to fine-loamy till
Topography: Depressional to strongly sloping to undulating crest
Drainage: Moderately well to rapidly drained
Stoniness: Non to exceedingly stony

Vegetation: Needle and thread (*Stipa comata*), June grass (*Koeleria macrantha*) and blue grama (*Bouteloua gracilis*) dominate the study area. Northern and western wheatgrasses (*Agropyron dasystachyum* and *smithii*), little club moss (*Selaginella densa*), pasture sage (*Artemisia frigida*), moss phlox (*Phlox hoodii*) and pin cushion cactus (*Mamillaria vivipara*) are common.

Soils: Five soil map units have been delineated; most are Orthic Dark Brown Chernozems. Some Eluviated, Rego and Calcareous Dark Browns also occur. Thin topsoils occur in one of the map units. Steep slopes, thin topsoils and extreme stoniness are common in two others. Soils are generally non-saline and non-sodic, although some map units are moderately alkaline. Soil organic carbon ranges from 1.7 to 2.6% off the trench and averages 1.3% on the trench.

Grazing History:

1987	91 cattle	May 1 to October 1
1988	91 cattle	May 1 to July 8
1989	91 cattle	May 1 to October 11
1990	574 AUM	
	306 cows	August 3 to September 16
1991	721 AUM	
	107 cow/calf pairs plus 478 yearlings	
	30 cows	July 29 to August 3
1992	235 AUM	July to August

4. Site Four

Legal: NE-21-18-19-W4M
Ecoregion: Mixed Grass
Parent Material: Fine-loamy till
Topography: Very gently to gently undulating or depressional
Drainage: Well to imperfectly drained
Stoniness: Non to moderately stony

Vegetation: Short and mid-grasses, with a variety of forbs, are common and dominate the vegetation. Dominant species are northern wheatgrass (*Agropyron dasystachyum*), needle and thread (*Stipa comata*) and June grass (*Koeleria macrantha*). Blue grama (*Bouteloua gracilis*) and bluegrass (*Poa spp.*) also occur. Little club moss (*Selaginella densa*), pasture sage (*Artemisia frigida*), pussytoes (*Antennaria spp.*) and snowberry (*Symphoricarpos alba*) are common throughout the study site.

Soils: Solonetzic Dark Brown Chernozems dominate two of the map units which comprise the majority of the site. There are some significant Orthic Dark Brown Chernozems as well as eroded Rego and Calcareous Dark Brown Chernozems. The Ah horizon in one of the map units on Rego and Calcareous Dark Brown Chernozems is eroded. Soil pH is slightly alkaline. Soils are neither saline nor sodic. Total organic carbon averages 1.9% on the trench and 2.8% off the trench.

Grazing History:

1987	34 cattle	May 1 to October 1
1988	34 cattle	May 1 to July 8
1989	34 cattle	May 1 to October 11
1990	640 AUM	
	39 cows	May to August 1
	10 cows	May 10 to August 3
	190 cows	June 19 to August 3
	10 bulls	May 10
	755 cows	October 12-15
1991	1042 AUM	
	46 cow/calf pairs plus 287 yearlings	July 11
	60 yearlings	May 17
	25 cow/calf pairs	May 31
	8 cow/calf pairs plus 6 yearlings	June 14
	28 cow/calf pairs	June 22
	18 yearlings	July 4-11
	809 cow/calf pairs	October 9-16
1992	322 AUM	

5. Milo Lateral Reclamation

Site 1 is seeded with a native species mix on the southern half and a non-native species mix on the northern half (Tables 1 and 2). Site 2 has the non-native species mix on the southern portion and the native species mix on the northern half. Sites 3 and 4 were seeded with native species. At Site 4, only half the exclosure was seeded.

Table 1. Milo Lateral native seed mix.

Species	Variety	% By Weight
Western Wheatgrass	Walsh	25
Northern Wheatgrass	Elbee	25
Slender Wheatgrass	Revenue	17
Canada Bluegrass	Reubens	8
Alkali Grass	Nuttall's	25

Table 2. Milo Lateral non-native seed mix.

Species	Variety	% By Weight
Crested Wheatgrass	Parkway	3
Russian Wild Rye	Swift	3
Streambank Wheatgrass	Sodar	6
Slender Wheatgrass	Revenue	3
Tall Wheatgrass	Orbit	7
Pubescent Wheatgrass	Greenleaf	6
Altai Wild Rye	Prairieland	12
Alfalfa	Rambler	12
Sanfoin	Common	33
Cicer Milkvetch	Oxley	17

B. Porcupine Hills Lateral

The Porcupine Hills RoW is 160 km long and 18 m wide, running from NW-6-20-2-W5 to NW-17-4-30-W4. Construction began in February and ended in May 1987. Topsoil was conserved through ditchline stripping, stockpiled on the working side of the RoW and replaced in summer 1987. Four study sites transect the Aspen Parkland, Montane and Fescue Grassland Ecoregions. The detailed list of plant species identified at each site is found in Appendix I B.

1. Rowland Site

Legal Location: NE 24-18-3-W5

Ecoregion: Aspen Parkland

Parent Material: Medium to moderately fine textured till

Topography: Undulating to gently rolling

Drainage: Moderately well to well drained

Stoniness: Non-stony

Vegetation: Vegetation is dominated by rough fescue (*Festuca campestris*), three flowered avens (*Geum triflorum*), Parry's oat grass (*Danthonia parryi*), northern wheatgrass (*Agropyron dasystachyum*) and Kentucky bluegrass (*Poa pratensis*). The first four species are native, while Kentucky bluegrass is non-native but has a low prominence value.

Soils: Soils are medium to moderately fine textured Calcareous Black Chernozems with inclusions of Orthic Black Chernozems. Topsoils range from 30 to 40 cm in depth, and are non-saline and non-sodic. Soil pH ranges from 7.3 to 7.7. Total organic carbon ranges from 0.2 to 5.4% and from 0.3 to 6.4% over the trench. Most soil parameters show little variability.

Grazing History:
1989 .... No data available
1990 .... No data available
1991 .... 200 cow/calf pairs .... 60 days
1992 .... 18 cows .... 4 months

2. Davies Site

Legal: NW-36-12-2-W5
Ecoregion: Aspen Parkland
Parent Material: Moderately fine textured till
Topography: Undulating to gently rolling
Drainage: Moderately well to well drained
Stoniness: Non-stony

Vegetation: Both aspen woodland and grasslands occur. Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratense*), rough fescue (*Festuca campestris*), white dutch clover (*Trifolium repens*), alsike clover (*Trifolium hybridum*) and wild strawberry (*Fragaria virginiana*) dominate.

Soils: Soils are uniformly textured Orthic and Rego Black Chernozems developed on till. Topsoils are less clayey than subsoils, and are 12 to 33 cm thick. Soils are non-saline and non-sodic with uniform cations and anions. Nitrates are very low throughout. Total organic carbon ranges from 0.2 to 4.9% and 0.2 to 3.8% on the trench. Soil pH ranges from 6.8 to 8.0.

Grazing History:
1989 .... 42 yearlings.................. June 1 to September 30
1990 .... 42 yearlings.................. June 1 to September 30
1991 .... 42 yearlings.................. June 1 to September 30
1992 .... 42 yearlings.................. June 1 to September 30

3. Waldron Site

Legal: SW-24-10-2-W5

Ecoregion: Fescue Grasslands

Parent Material: Medium textured till, glacio-fluvial (gravelly in places)

Topography: Gently undulating to gently rolling

Drainage: Moderately well to well drained

Stoniness: Non to moderately stony

Vegetation: Foothills Fescue and Mixed Prairie grassland communities are present. Dominant species are rough fescue (*Festuca campestris*), northern wheatgrass (*Agropyron dasystachyum*), pasture sage (*Artemisia frigida*), Idaho fescue (*Festuca idahoensis*) and little club moss (*Selaginella densa*). Little club moss, western porcupine grass, tufted white prairie aster, wild vetch and blazing star are indicative of a drier site where prairie species compete with the fescue community.

Soils: Soils vary more than at other sites on this pipeline. Four soil map units are delineated, with soils dominated by Orthic and Rego Black Chernozems. Soil pH ranges from 7.1 to 8.4. Total organic carbon ranges from 0.4 to 5.2% and from 1.3 to 3.7% over the trench.

Grazing History:

1989	54 AUM	No dates
1990	No data available	
1991	93 AUM	Holding field
	109 cow/calf pairs	August 14-18
	18 heifers and 118 cow/calf pairs	August 18-20
	49 cow/calf pairs	September 19
	59 cow/calf pairs	October 3-7
	158 dry cows	November 2-4
1992	98 AUM	Holding field
	1217 yearling heifers	September 25-27
	95 cow/calf pairs	October 15-18
	605 heifers and 92 dry cows	October 29-31

4. Cyr Site

Legal: NE-36-4-1-W5

Ecoregion: Montane

Parent Material: Medium textured, glacio-fluvial (gravelly)

Topography: Gently undulating

Drainage: Moderately well to well

Stoniness: Moderately to very stony

Vegetation: This study area is morainal with a rolling topography. It covers the Castle River south to Waterton National Park and the majority of the Porcupine Hills outside of the forest reserve. Dominant plant species include Parry's oat grass (*Danthonia parryi*), rough fescue (*Festuca campestris*), American hedysarum (*Hedysarum alpinum*) and Idaho fescue (*Festuca idahoensis*).

Soils: Soils are gravelly, sandy loam to loam textured Orthic Black Chernozems with similar profiles. Topsoils range from 19 to 30 cm, and average 24 cm. Soils are generally non-saline and non-sodic with little variability. Soil pH varies within the root zone from 5.3 to 6.4. Total organic carbon ranges from 2.9 to 7.2% on the trench and 1.0 to 8.0% off the trench. There is more total organic carbon at depth in the trench at this study site than at any of the other study sites on this pipeline.

Grazing History:
1989 .... 38 cow/calf pairs.......... June 1 to September 30
1990 .... 35 cow/calf pairs.......... June 1 to September 30
1991 .... 80 cow/calf pairs.......... June 1 to July 31
1992 .... 120 yearlings................ June 1 to July 31

5. Porcupine Hills Lateral Reclamation

Reclamation was completed in fall 1987. The seed mix (Table 3) was applied at a rate of 10 kg ha[1] using a Truax Rangeland Seed Drill. Exclosures were established in the spring of 1988, prior to cattle grazing.

Table 3. Porcupine Hills Lateral seed mix.

Species	Variety	% By Weight
Canada Bluegrass	Reubens	2
Hard Fescue	Durar	3
Rough Fescue	Common	14
Sheeps Fescue	Covar	3
June Grass	Common	3
Northern Wheatgrass	Elbee	15
Slender Wheatgrass	Revenue	10
Streambank Wheatgrass	Sodar	45
Alfalfa	Rangelander	5

III. STUDY DESIGN AND METHODS

A. Grazing Exclosures

A typical plot layout within and outside of the Porcupine Hills grazing exclosures is depicted in Figure 2. Grazing exclosures measuring 50 by 50 m were established on all study sites. Exclosures included the RoW and adjacent undisturbed native grassland. Exclosures were constructed after completion of seeding and prior to cattle grazing.

Grazing exclosures varied at the Milo sites. At Site 1, the 50 by 100 m exclosure was seeded to non-native species on the north and native species on the south half. The off-RoW transect was located west of the RoW, except on the unfenced north plot where the terrain changes, necessitating that it be located east of the RoW. At Site 2, the 50 by 100 m exclosure was seeded to non-native species on the south half and native species on the north. At both of these sites, there are 16 permanent line transects, 80 productivity plots and 20 production cages. At Site 3, the 50 by 178 m exclosure is located on a southeast facing slope. There are eight permanent line transects, forty productivity plots and ten utilization plots. The Site 4 exclosure is 50 by 100 m. The south half was seeded with native species, the north half was not seeded. There are nine permanent line transects and an additional line transect over the ditchline in the unseeded area. There are 60 productivity plots and 10 production cages.

B. Transects

Four 30 m line transects were established both inside and outside the exclosure (eight per site). Transects on the RoW were located on work, trench and spoil areas with a 10 m buffer between the exclosure fence and the start of each transect to ensure that cattle trailing and grazing along the exclosure fenceline did not impact on the permanent line transects.

C. Cover

Vegetation within and outside the exclosures was measured using 0.1 m^2 (25 by 40 cm) quadrats. 30 quadrat locations were randomly generated by a computer for each transect prior to the initiation of the study (240 per site). These locations were used for all years of the study. The locations of the quadrats started from the end of the transect closest to the exclosure fenceline. Cover was assessed using the following classes and associated midpoints:

1 = 0.5	2 = 2.5	3 = 15.0	4 = 37.5
5 = 62.5	6 = 85.0	7 = 97.5	

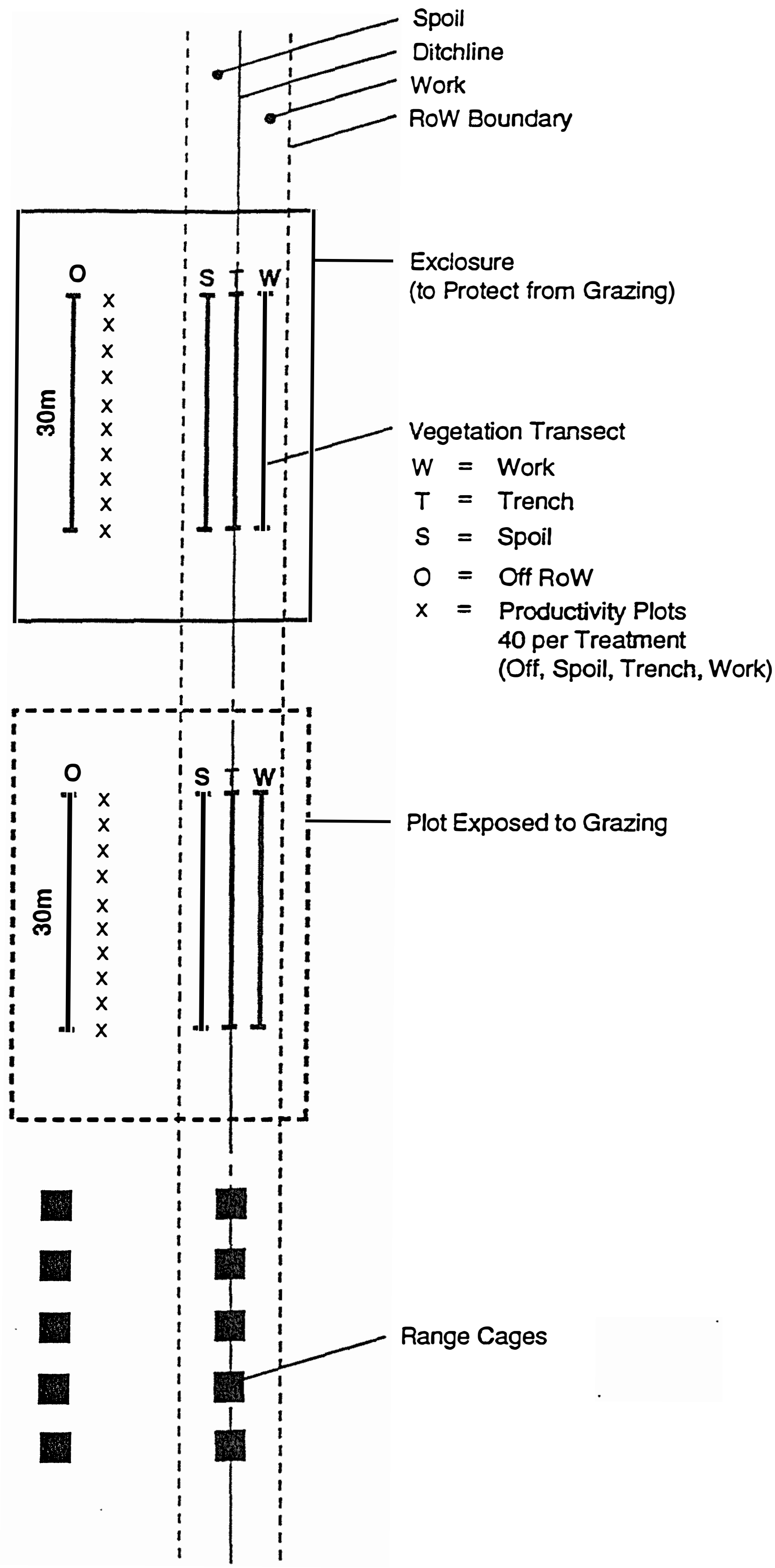


Figure 2. Typical plot layout.

Species and associated cover classes for each quadrat were recorded in the field. Sampling was done during the growing season peak, generally late July or early August. Percent cover was determined by averaging the 30 midpoint cover classes for each plant species. Total cover was determined by summing the average percent cover for all of the species in each transect. Percent species composition was determined by dividing average percent cover for each plant species by the total average percent cover and multiplying by 100. Percent frequency for each plant species was determined by dividing the total number of quadrats in which the species occurred by the total number of quadrats for the particular transect, then multiplying by 100 to express as a percentage. The prominence value for each species was determined by multiplying the square root of the percent frequency by percent composition.

D. Productivity

Productivity was measured at the end of each growing season, and was sampled by clipping 10 by 10 cm plots to a one cm height. Ten plots were randomly located within each of the grazed and the ungrazed treatments (trench, work, spoil and off-RoW). Eighty plots were clipped per site. Samples were oven dried for 24 hours at 65 ^{0}C using a Precision Scientific E Series Oven, Model 18 EM with mechanical ventilation and a sensitivity of +/- 0.25 ^{0}C. Samples were weighed using a Nexus balance scale with a 0.1 g sensitivity.

E. Cattle Utilization

Production cages, 1 by 1 m in size, were used to measure herbage consumption. There were ten cages per site, five on the trench and five off the RoW. Sample size was increased by subdividing each plot into two 0.25 m^2 plots. Off-RoW cages were 30 m from the edge of the RoW, perpendicular and parallel to the trench cages. A 20 m buffer was established between the end of the permanent line transects and the cages. The first cage on the trench was randomly located by generating a random number between one and five, multiplying it by two and adding it to the 20 m buffer; the remaining four cages were spaced 10 m apart. Cages were not put in the same location more than once throughout the study. At Milo Site 3, there were no production cages. Productivity was assessed by clipping 1 by 1 m plots from within the exclosure, while grazed plots were located adjacent to the exclosure at the same slope position as ungrazed plots. Plots were clipped at the end of the grazing season (usually October) of each year. Samples were oven dried and weighed to the nearest 0.10 grams. Oven drying followed the procedure outlined under productivity above.

F. Statistical Analyses

Analysis of Variance was used to detect significant effects and interactions of production means. Treatment (control, spoil, trench and work area), year, and seeding type were classified as fixed effects while site was classified as a random effect. Interaction between the fixed effects and site was used as the error term for an F-test. Analysis followed convention as outlined in the SPSSx Users Guide. Multiple comparisons of means of significant (0.05 level) effects and interactions were done using an SNK multiple range test (Steel and Torrie 1980). Porcupine and Milo were analysed as individual data sets. Means presented are averages of all sites within each data set. Additional statistical information is presented in Appendix II.

Raw utilization data were purged of zero and extreme data values. Grazed and ungrazed raw data were averaged across site, and the resulting means were used to calculate utilization. This generated a more reliable estimate of utilization than if it had been calculated before averaging.

Changes in cover were evaluated by computing a Dissimilarity Matrix of the year by treatment by grazing interaction for the Porcupine Hills sites (32 cells) and year by treatment by grazing by seed type interaction for the Milo sites (56 cells). Cover was averaged across sites and the averaged file was used to compute the Dissimilarity Matrix. Matrices were calculated using squared Euclidean distances as the measure of dissimilarity (SPSSx Users Guide). Squared Euclidean distances are calculated using the following formula:

$$\text{Dissimilarity} = \_\ (\text{cover}_{i1} - \text{cover}_{i2})^2$$

Where cover_{i1} = cover of species i on treatment 1

cover_{i2} = cover of species i on treatment 2

for species i = 1 to 251

With the above formula, a single value is produced (Dissimilarity Index) to compare the vegetation cover of two treatments. Porcupine Hills had 32 data points (4 years by 4 treatments by 2 grazing levels) while Milo had 56 (4 years by 4 treatments by 2 grazing levels by 2 seed sources, which should be 64, but only one set of control data for two seed sources was collected). Dissimilarity Indices were calculated for all possible data point pairs, and a Dissimilarity Matrix was produced. Dissimilarity Matrices were plotted in hyperspace, which is imaginary space where the distance between points is proportional to their dissimilarity (multidimensional scaling algorithms). Two dimensions were sufficient to explain 90% of the variation in all dissimilarity matrices generated. Output from multidimensional scaling was split into individual interactions and plotted for visual comparisons. Distances between points on the resulting graphs are proportional to the dissimilarity index of those points (distance is relative to how similar vegetation cover is).

Cover was analysed as outlined above for vegetation including bare ground and litter cover, and for vegetation alone.

Significant effects for bare ground and litter cover were further analyzed using the same Analyses of Variance models as for the production analyses. Cover values for individual vegetation species were not analyzed statistically, but were graphed for visual interpretation. Graphs of individual species represent means that are averaged across sites and grazing treatments. Site and/or grazing effects were only analysed where there was evidence that there was a reliable effect on vegetation cover, that also differed from trends in vegetation cover found using the means (averaged across site and/or grazing). A reliable effect was defined as a consistent trend in cover over time and space. Kentucky bluegrass was the only species with a site or grazing specific response to the treatments applied. Site or grazing specific cover trends of other species were either represented by averaged means or else the trends were not consistent.

IV. RESULTS AND DISCUSSION

A. Production

Pipeline construction and reclamation generally resulted in a depression in grass production relative to the control immediately following the disturbance (Table 4). Grass production at the Milo sites increased significantly from 1988 to 1991 on disturbed areas (spoil, trench and work area), equaling or exceeding grass production on the undisturbed control by the fourth year after pipeline construction (Table 4). Grass production on the spoil increased by the greatest magnitude, from 210 to 1600 kg ha^{-1}, in 1988 and 1991, respectively. Grass production trends at the Porcupine Hills sites followed a similar pattern as the Milo sites (Table 4). There were no significant effects or interactions in grass production, although some general trends were apparent. Grass production was lower on disturbed areas one year after pipeline construction. Grass production on all treatments, including the control, increased (insignificantly) from 1988 to 1991.

Forb production response to pipeline construction was opposite to grass production. Most pioneer species in the seed bank are forbs and would therefore be expected to increase with disturbance in the short-term. At the Milo sites, forb production was higher on disturbed areas than on the control (Table 4), peaking on the spoil in 1990 (950 kg ha^{-1}) and on the work area in 1988 (640 kg ha^{-1}). Forb production was consistently higher on the trench than on the control, but not significantly so. Forb production at the Milo sites was variable, with an overall lack of statistical significance. This was affected by the presence or absence of *Artemisia frigida*.

Table 4. Grass, forb and total herbaceous production (kg ha^{-1}) means for main effects and two way interactions for the Milo and Porcupine Hills sites.

Milo	Control			Spoil			Trench			Work			Year Mean	
Grass														
1988	460	a	x	210	a	z	390	a	y	470	a	y	380	y
1989	560	a	x	470	a	z	720	a	xy	510	a	y	560	xy
1990	630	a	x	1000	a	y	710	a	xy	980	a	x	830	xy
1991	860	b	x	1600	a	x	900	b	x	1080	b	x	1110	x
Treatment Mean	630	a		820	a		680	a		760	a			
Forb														
1988	90	b	x	100	b	y	270	ab	x	640	a	x	270	x
1989	100	b	x	650	a	x	270	ab	x	130	b	y	280	x
1990	60	b	x	950	a	x	240	b	x	190	b	y	360	x
1991	100	a	x	560	a	x	230	a	x	80	a	y	240	x
Treatment Mean	90	b		560	a		250	b		260	b			
Total Herbaceous														
1988	540	ab	x	310	b	z	660	ab	x	1110	a	x	660	x
1989	660	a	x	1120	a	y	980	a	x	630	a	x	850	x
1990	700	b	x	1950	a	x	950	b	x	1180	b	x	1190	x
1991	100	a	x	2150	a	x	1130	b	x	1160	b	x	1350	x
Treatment Mean	960	a		1380	a		930	a		1020	a			

Porcupine Hills	Control			Spoil			Trench			Work			Year Mean	
Grass														
1988	1430	a	x	1300	a	x	810	a	x	920	a	x	1120	x
1989	2030	a	x	2670	a	x	1980	a	x	1940	a	x	2150	x
1990	2040	a	x	2760	a	x	1540	a	x	2380	a	x	2180	x
1991	2540	a	x	2180	a	x	1780	a	x	2070	a	x	2140	x
Treatment Mean	2010	a		2230	a		1530	a		1830	a			
Forb														
1988	350	a	x	1350	a	x	770	a	x	690	a	x	790	x
1989	390	a	x	920	a	x	330	a	x	590	a	x	560	x
1990	460	a	x	430	a	x	380	a	x	370	a	x	410	x
1991	460	a	x	1290	a	x	640	a	x	540	a	x	730	x
Treatment Mean	420	a		1000	a		530	a		550	a			
Total Herbaceous														
1988	1790	a	x	2650	a	x	1580	a	x	1620	a	x	1910	x
1989	2420	a	x	3590	a	x	2310	a	x	2540	a	x	2710	x
1990	2500	a	x	3190	a	x	1920	a	x	2750	a	x	2590	x
1991	3000	a	x	3480	a	x	2410	a	x	2610	a	x	2880	x
Treatment Mean	2430	ab		3230	a		2050	b		2380	ab			

Means in the same category (ie. grass, forb, total herbaceous), for each column (xyz) and row (abc) that have the same letter, are not significantly different ($P < 0.05$).

Trends on disturbed areas at the Porcupine Hills sites were not consistent with those of Milo (Table 4). Forb production on all disturbed treatments was greater than on the control in 1988, declined from 1988 to 1990, then increased in 1991. High variability resulted in a lack of significance. However, an overall trend of increased forb production with disturbance was apparent. Forbs will often increase immediately after disturbance as pioneer species become dominant, then decline as those pioneer species are replaced by longer-living members of the plant community.

Total herbaceous production at the Milo sites (Table 4) generally increased with time, significantly so on the spoil. This increase is attributed to the increase in grasses, as forbs generally remained stable or declined over time. After four years, production on the spoil was significantly higher than on the other three treatments (2150 kg ha^{-1}). A similar trend was evident at the Porcupine Hills sites (Table 4). Again, total herbaceous production was highest on the spoil, with the other treatments not significantly different. Higher variability at the Porcupine Hills sites resulted in fewer significant differences compared to the Milo sites. The higher production on the spoil at the Milo sites was likely due to the increased number of high biomass species such as western and northern wheatgrass, although there is no indication why these species would be more dominant on the spoil treatment. Bare ground and litter on the spoil was less than on the other disturbed treatments, with live vegetation a higher component of ground cover and contributing to higher production values. The control had a high little club moss cover compared to any of the disturbed treatments, which is low in productivity.

B. Cover

Cover is presented as dissimilarity graphs to show overall trends. To follow these graphs, focus on the quadrant in which the control is located, then view the quadrant location of each disturbed treatment relative to the control. Follow the trend direction by beginning with the shaded symbol.

1. Milo Sites

If litter and bare ground cover are included, areas seeded to native (Figure 3) and non-native (Figure 4) species, particularly trench and spoil areas, trended towards controls (note movement towards the upper right hand quadrant near the control). Work area cover varied. When litter and bare ground were excluded and matrices based on plant cover, disturbed areas were less similar to

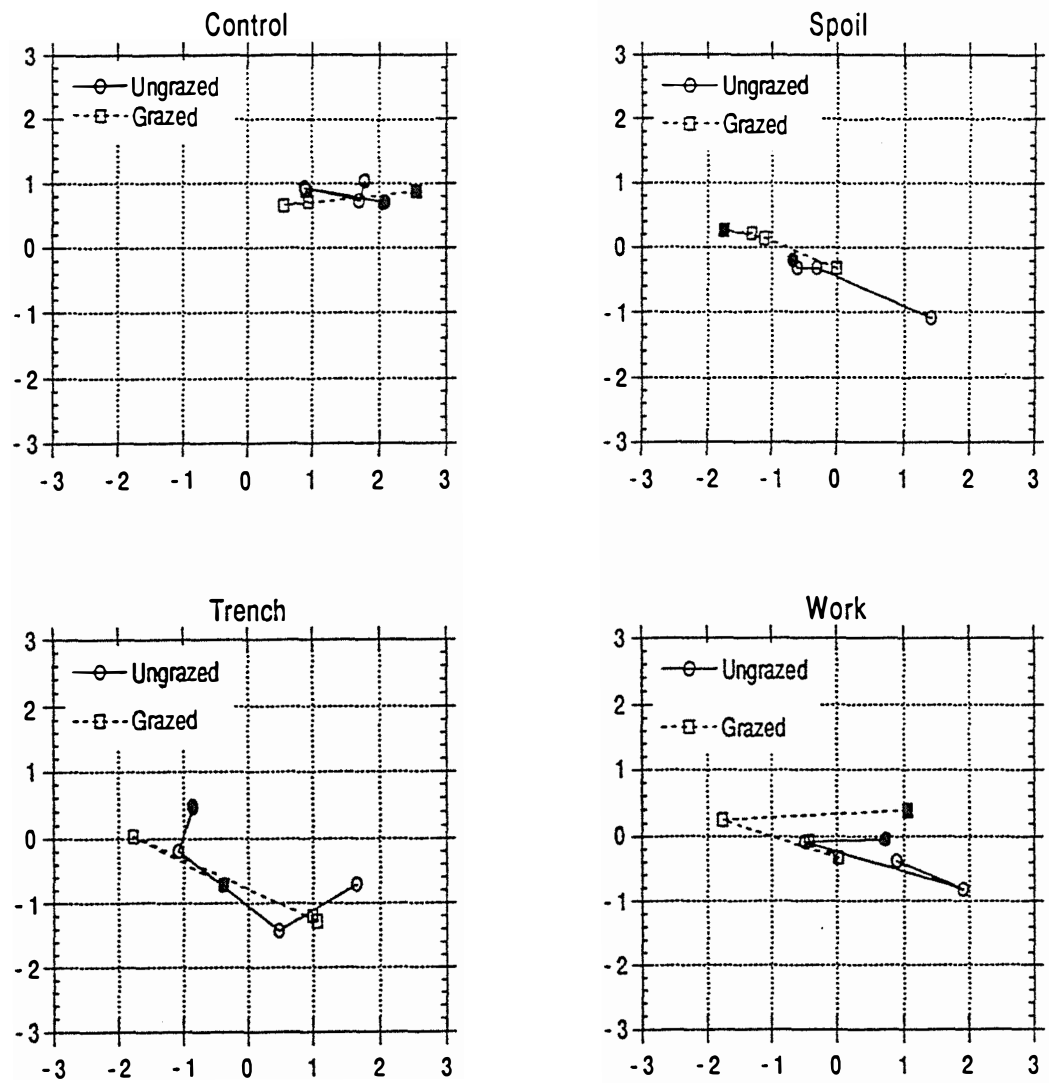


Figure 3. Graphical representation of dissimilarity matrices of cover data for Milo sites seeded to native species; bare ground and litter cover are included. Begin at the shaded symbol, which represents the 1988 data, and follow either the dashed or solid line.

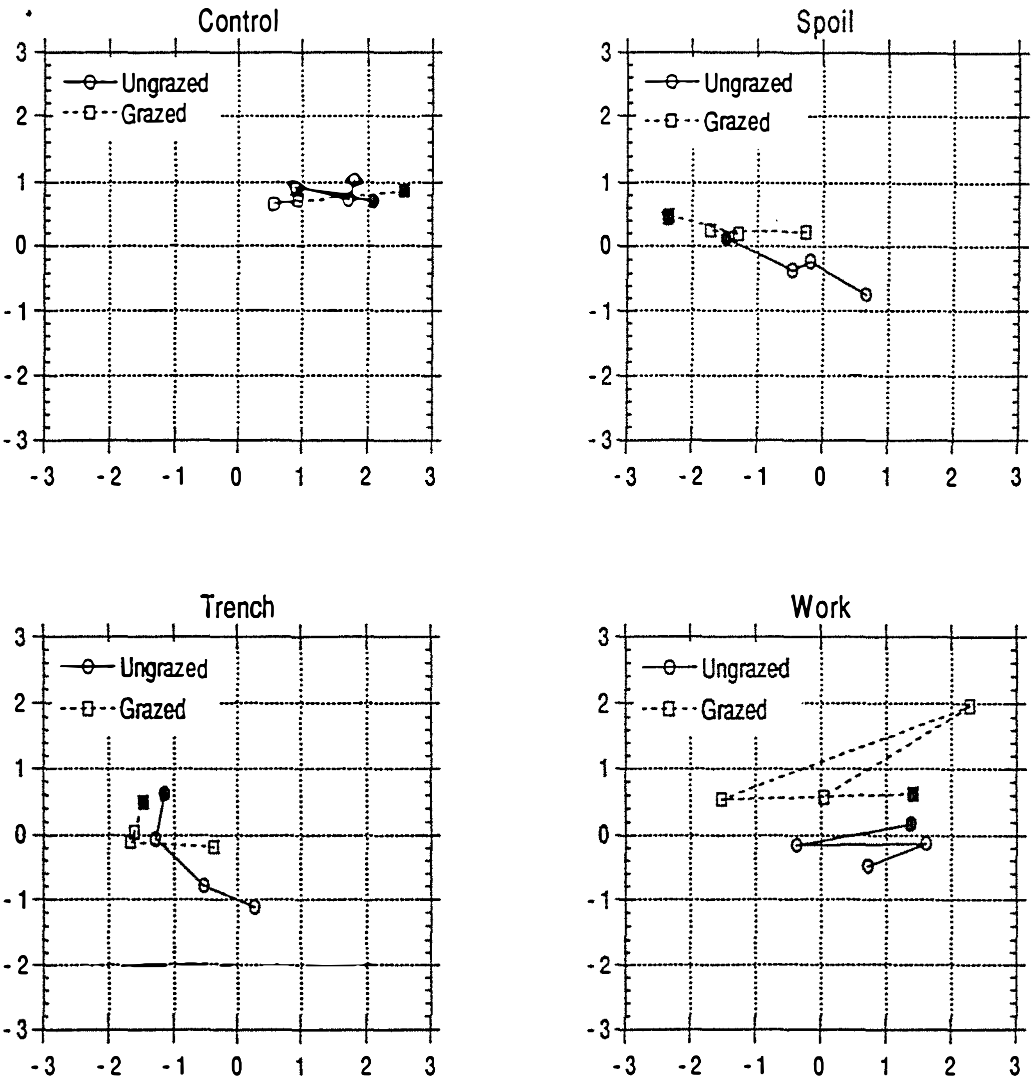


Figure 4. Graphical representation of dissimilarity matrices of cover data for Milo sites seeded to non-native species; bare ground and litter cover are included. Begin at the shaded symbol, which represents the 1988 data, and follow either the dashed or solid line.

controls with time (Figures 5 and 6). Work area cover was variable if seeded to non-native species (Figure 6) but consistent if seeded to native species (Figure 5). Thus litter and bare ground cover were becoming more similar to undisturbed controls, but species cover was becoming less similar.

Dissimilarity matrices for on-RoW versus off-RoW varied (Figure 7). When litter and bare ground were included, cover on RoW seeded to native or non-native species became more similar to off-RoW areas. When litter and bare ground were excluded, trends were less apparent. Thus litter and bare ground were moving towards predisturbance levels but species composition was not.

The above general observations are supported by individual analyses of bare ground and litter cover for areas seeded to native (Table 5) and non-native species (Table 6) at the Milo sites. Where native species were seeded, bare ground was significantly higher on all disturbed areas in 1988 and 1989 than on the control, except for the work area in 1988. Litter cover was significantly lower on disturbed areas than on the control in 1988 or 1989 (Table 5). In 1991, there was no significant difference in bare ground between control and disturbed areas; litter cover on the trench significantly exceeded litter cover on the control, spoil and work area. Trends were similar for bare ground and litter cover on areas seeded to non-native species (Table 6). Bare ground was stable on the control throughout the four year study, highest in 1988 or 1989 for disturbed areas, then declining on disturbed areas significantly through to 1991. The main difference between areas seeded to native and non-native species is that in 1991, bare ground was still significantly higher on disturbed areas than on the control for areas seeded to non-native species. Litter trends for areas seeded to non-native and native species were also similar. Litter cover on the spoil and trench was lowest in 1988, increasing significantly by 1991. Litter cover on the work area did not vary significantly over the four years. In 1991, there was significantly higher litter cover on disturbed areas than on the control, likely due to the higher biomass producing non-native species.

There were trends in dominant species cover for areas seeded to native (Figure 8) and non-native species (Figure 9). Northern wheatgrass, western wheatgrass, pasture sage and needle and thread cover on the control from 1988 to 1991 was more stable than little club moss cover, which was highest in 1988 and lowest in 1991. Little club moss can be mistaken for litter if measured under dry conditions. Its cover was absent or low on the trench and spoil for areas seeded to both native and non-native species. This absence would explain some cover dissimilarity discussed earlier. On the work area, there were large differences in little club moss cover among years, especially in areas seeded to non-native species. Needle and thread cover was reduced on disturbed areas, especially the spoil and trench, compared to the control for areas seeded to both native and non-

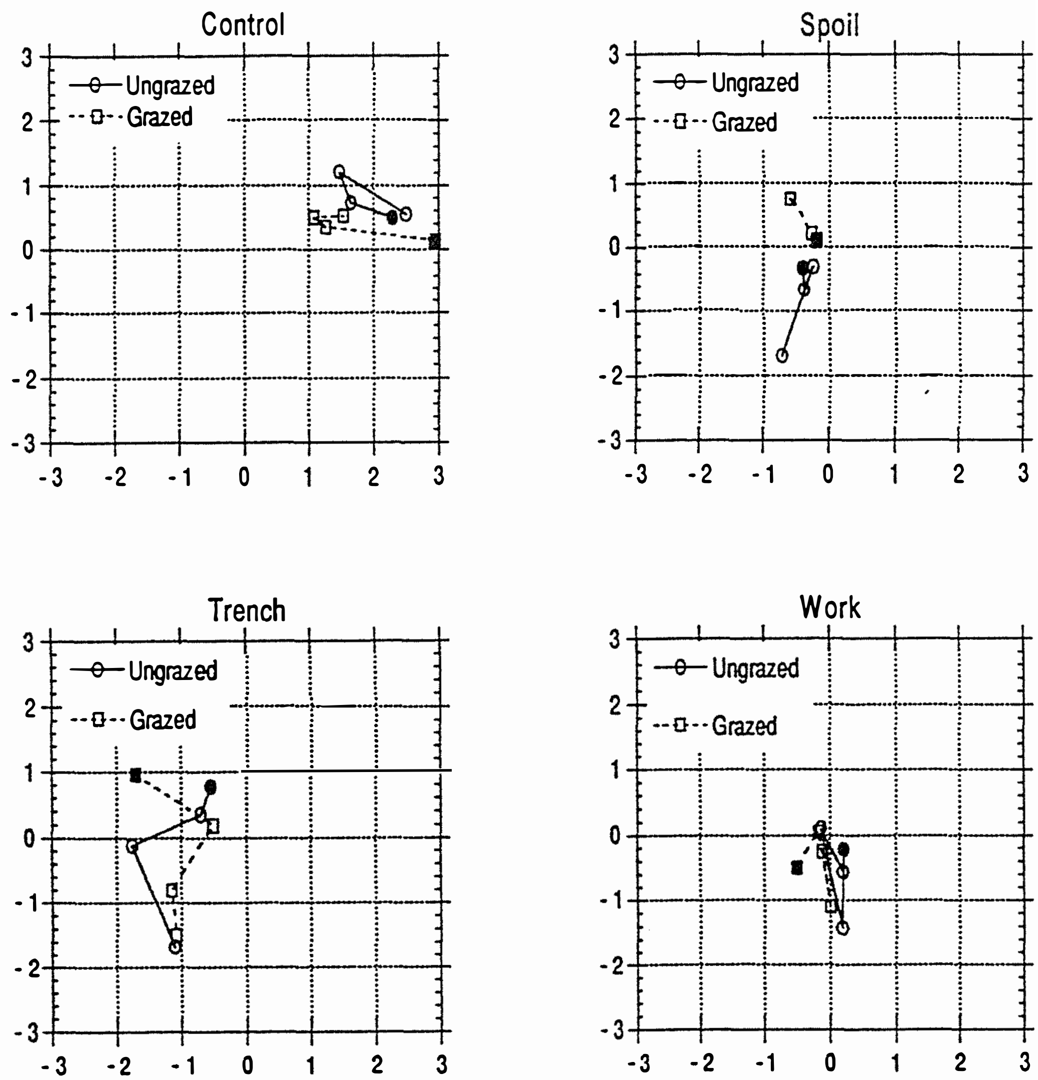


Figure 5. Graphical representation of dissimilarity matrices of cover data for Milo sites seeded to native species; bare ground and litter cover are excluded. Begin at the shaded symbol, which represents the 1988 data, and follow either the dashed or solid line.

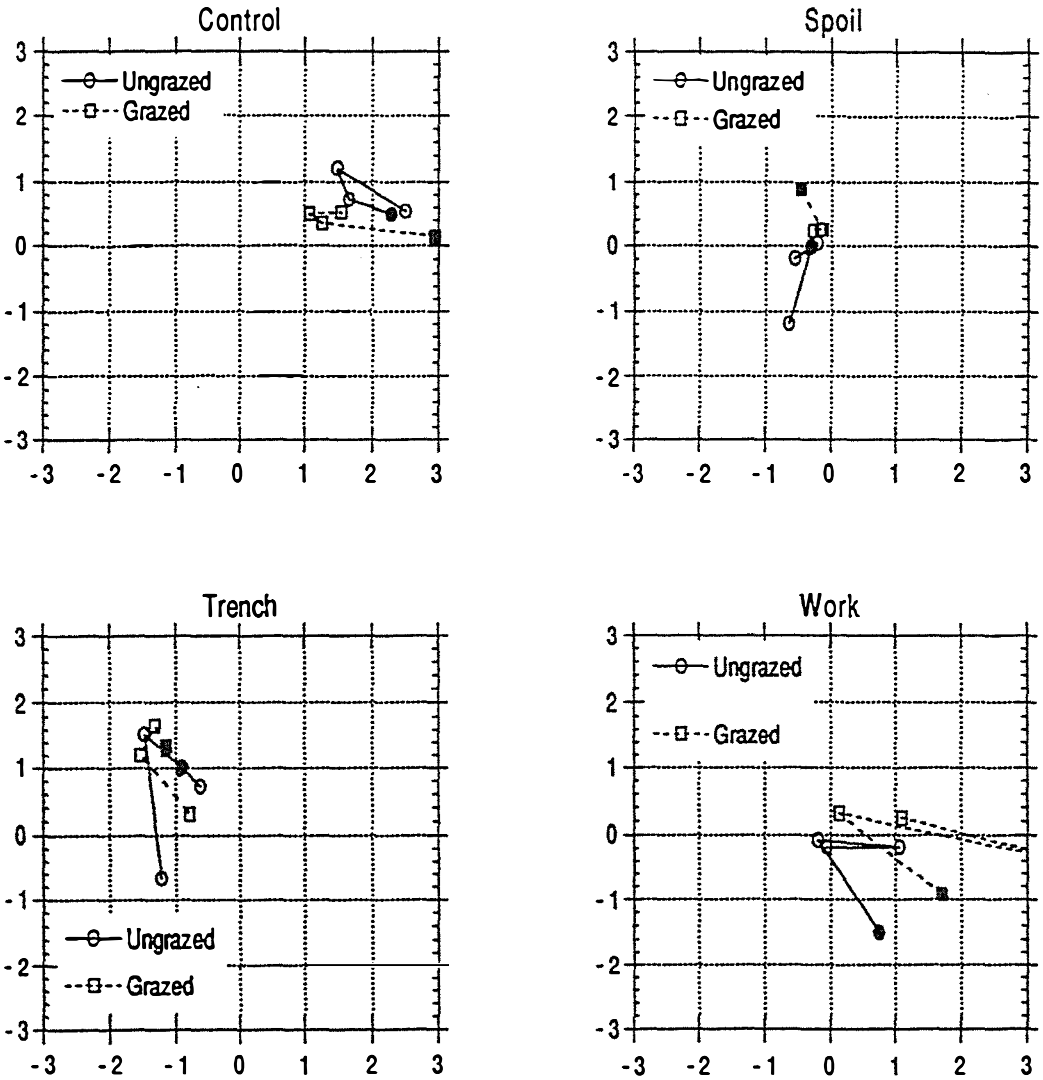


Figure 6. Graphical representation of dissimilarity matrices of cover data for Milo sites seeded to non-native species; bare ground and litter cover are excluded. Begin at the shaded symbol, which represents the 1988 data, and follow either the dashed or solid line.

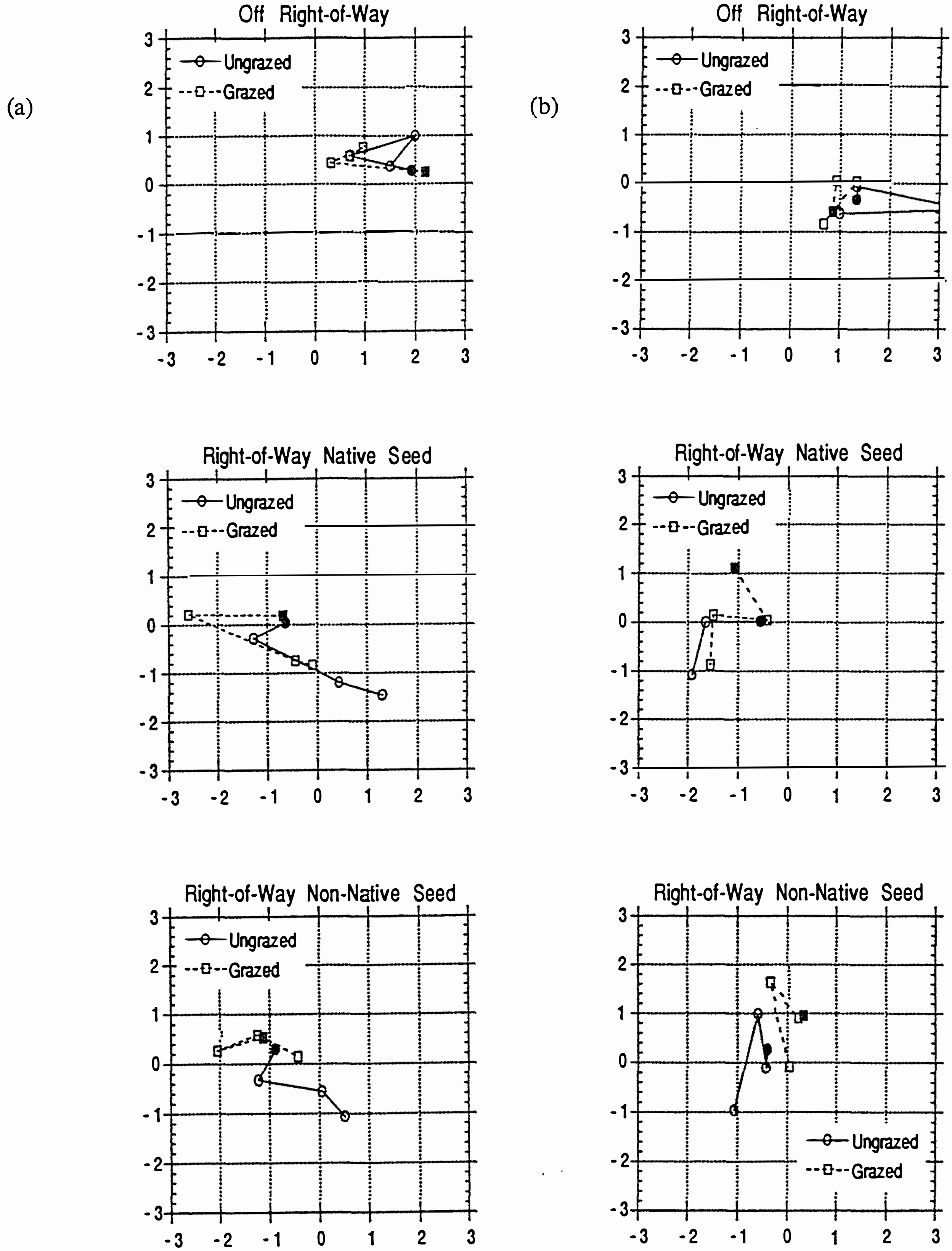


Figure 7. Graphical representation of dissimilarity matrices of cover data for Milo sites seeded to non-native and native species; bare ground and litter cover are (a) included and (b) excluded. Begin at the shaded symbol, which represents the 1988 data, and follow either the dashed or solid line.

Table 5. Percent cover of bare ground and litter for main effects and two way interactions for the Milo sites seeded to native species.

	Control			Spoil			Trench			Work			Year Mean	
Bare Ground														
1988	21	b	x	70	a	x	57	a	y	34	b	y	45	y
1989	40	b	x	74	a	x	77	a	x	74	a	x	66	x
1990	29	b	x	68	a	x	42	b	yz	41	b	y	45	y
1991	31	a	x	42	a	y	34	a	z	52	a	y	40	y
Treatment Mean	31	a		63	a		52	a		51	a			
Litter														
1988	48	a	x	27	b	y	27	b	y	36	b	y	35	x
1989	36	a	x	25	a	y	25	a	y	28	a	y	29	x
1990	40	bc	x	33	c	xy	60	a	x	51	ab	x	46	x
1991	38	b	x	40	b	x	59	a	x	47	b	x	47	x
Treatment Mean	40	a		33	a		43	a		40	a			

Means in the same category (ie. bare ground, litter), for each column (xyz) and row (abc) that have the same letter, are not significantly different ($P < 0.05$).

Table 6. Percent cover of bare ground and litter for main effects and two way interactions for the Milo sites seeded to non-native species.

	Control			Spoil			Trench			Work			Year Mean	
Bare Ground														
1988	15	d	x	83	a	x	64	b	xy	32	c	z	48	y
1989	28	b	x	70	a	y	74	a	x	71	a	x	61	x
1990	21	b	x	70	a	y	65	a	xy	24	b	y	45	x
1991	25	b	x	48	a	z	55	a	y	49	a	z	44	x
Treatment Mean	22	b		68	a		64	a		44	a			
Litter														
1988	47	a	x	18	b	y	18	b	z	41	a	x	31	x
1989	32	a	y	32	a	xy	30	a	y	32	a	x	31	x
1990	30	a	y	31	a	xy	35	a	xy	43	a	x	35	x
1991	27	b	y	40	a	x	46	a	x	46	a	x	39	x
Treatment Mean	34	a		30	a		32	a		40	a			

Means in the same category (ie. bare ground, litter), for each column (xyz) and row (abc) that have the same letter, are not significantly different ($P < 0.05$).

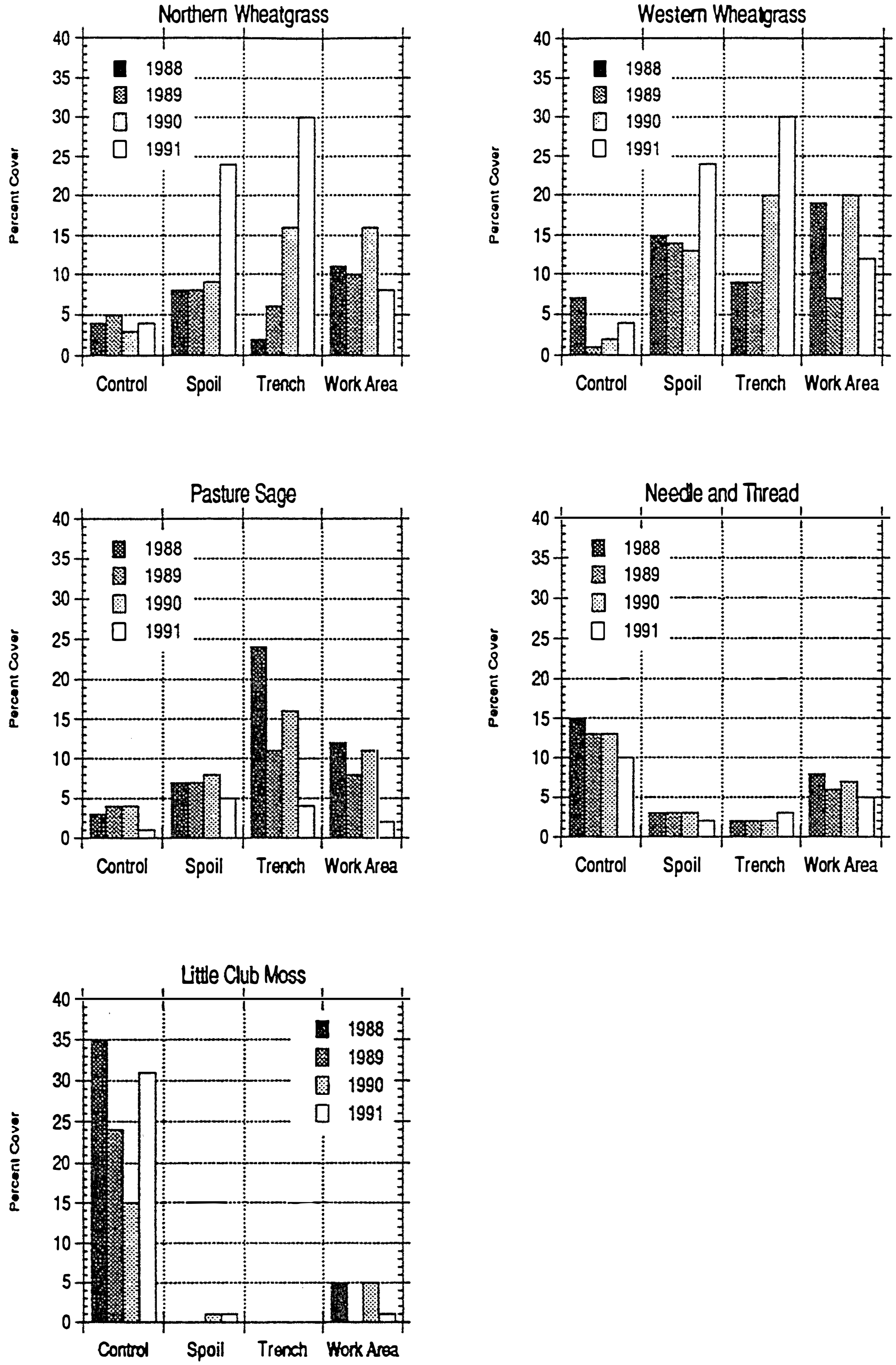


Figure 8. Percent cover of dominant species by year and treatment at the Milo sites seeded to native species.

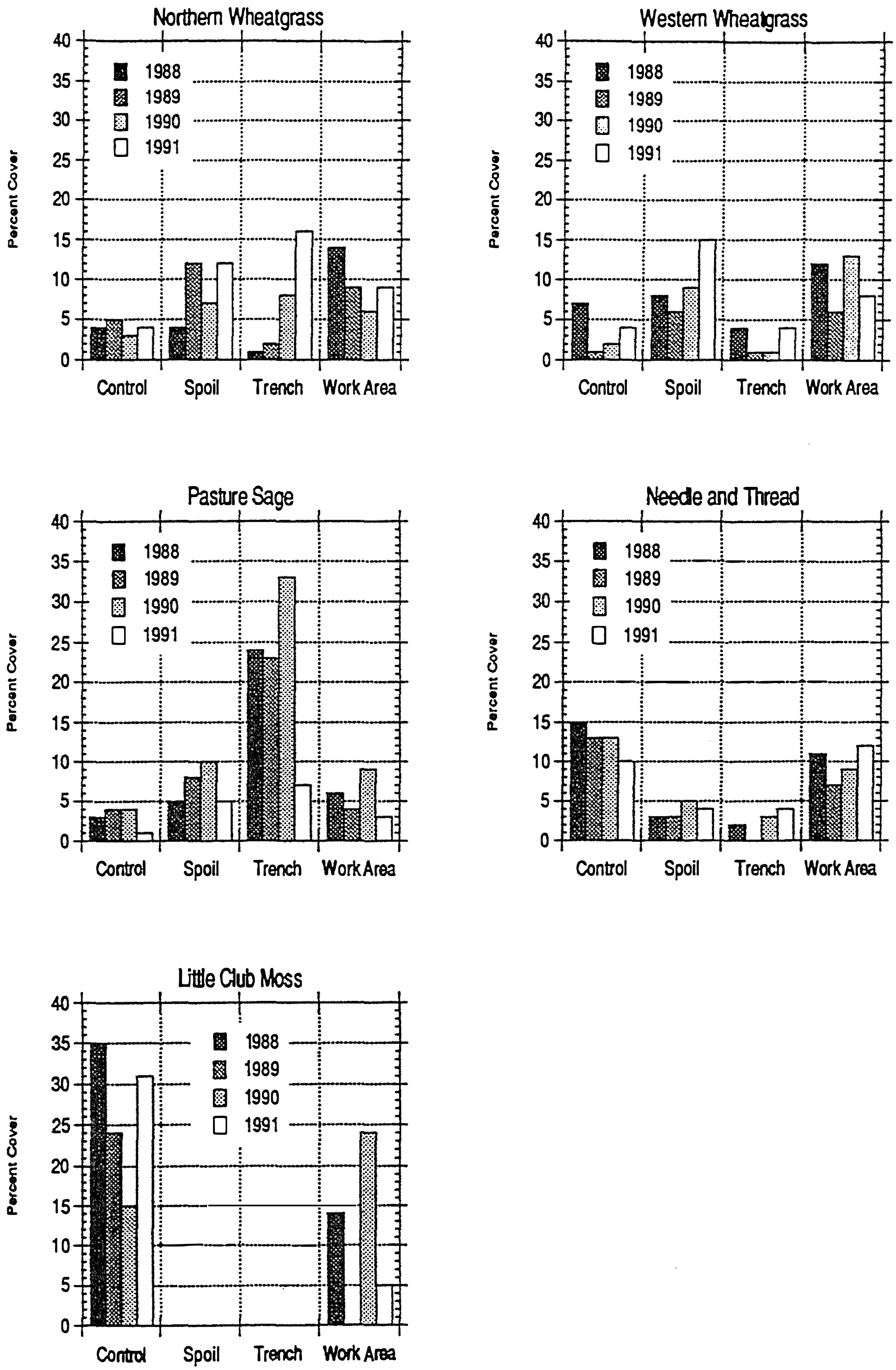


Figure 9. Percent cover of dominant species by year and treatment at the Milo sites seeded to non-native species.

native species. Pasture sage cover was greater on disturbed areas compared to the control for areas seeded to both native and non-native species. It increased most on the trench for three years, then was below 5% by 1991.

Dissimilarity graphs discussed earlier can be explained by western and northern wheatgrass cover. Northern wheatgrass on the trench and spoil increased over time in areas seeded to native and non-native species. Western wheatgrass cover increased on the spoil and trench over time for areas seeded to native species, but not for areas seeded to non-native species. Such cover increase of these dominant species over time could explain the trench and spoil becoming less similar to the control. Cover variability of these species on the work treatment could account for the variability in the dissimilarity matrices discussed previously.
There were no discernible effects of grazing on cover. Grazing disturbed areas resulted in 8 to 10% more bare ground and less litter than in the controls, but the difference was not significant for areas seeded to native or non-native species. Grazed and ungrazed areas were similar in species cover, whether litter and bare ground were included (Figures 3 and 4) or excluded (Figures 5 and 6).

2. Porcupine Hills Sites

Cover at Porcupine Hills sites on disturbed areas evolved towards undisturbed levels whether litter and bare ground were included (Figure 10) or excluded (Figure 11). Disturbed areas were less similar to controls the first year but more similar the fourth year after disturbance. On disturbed areas, bare ground was highest in 1988 and lowest in 1991, while litter was lowest in 1988 and highest in 1991 (Table 7). Both bare ground and litter evolved to predisturbance levels by 1991.

Dissimilarity matrices for on versus off-RoW varied (Figure 12). When litter and bare ground were included, cover on RoW became quite similar to off-RoW areas with time. When litter and bare ground were excluded from cover, trends were still apparent but the movement was not as fast.

Individual species cover varied between disturbed and control treatments (Figure 13). Rough fescue and Idaho fescue cover were reduced by disturbance. Slender wheatgrass was dominant on disturbed areas, but absent in the control. Kentucky bluegrass cover was depressed on the spoil and trench in 1988, but increased through 1991 to levels of the control. Timothy cover was relatively stable except for an increase on the trench in 1989 and 1990. Dissimilarity between disturbed areas and the control can be explained by dissimilarity in slender wheatgrass, Idaho

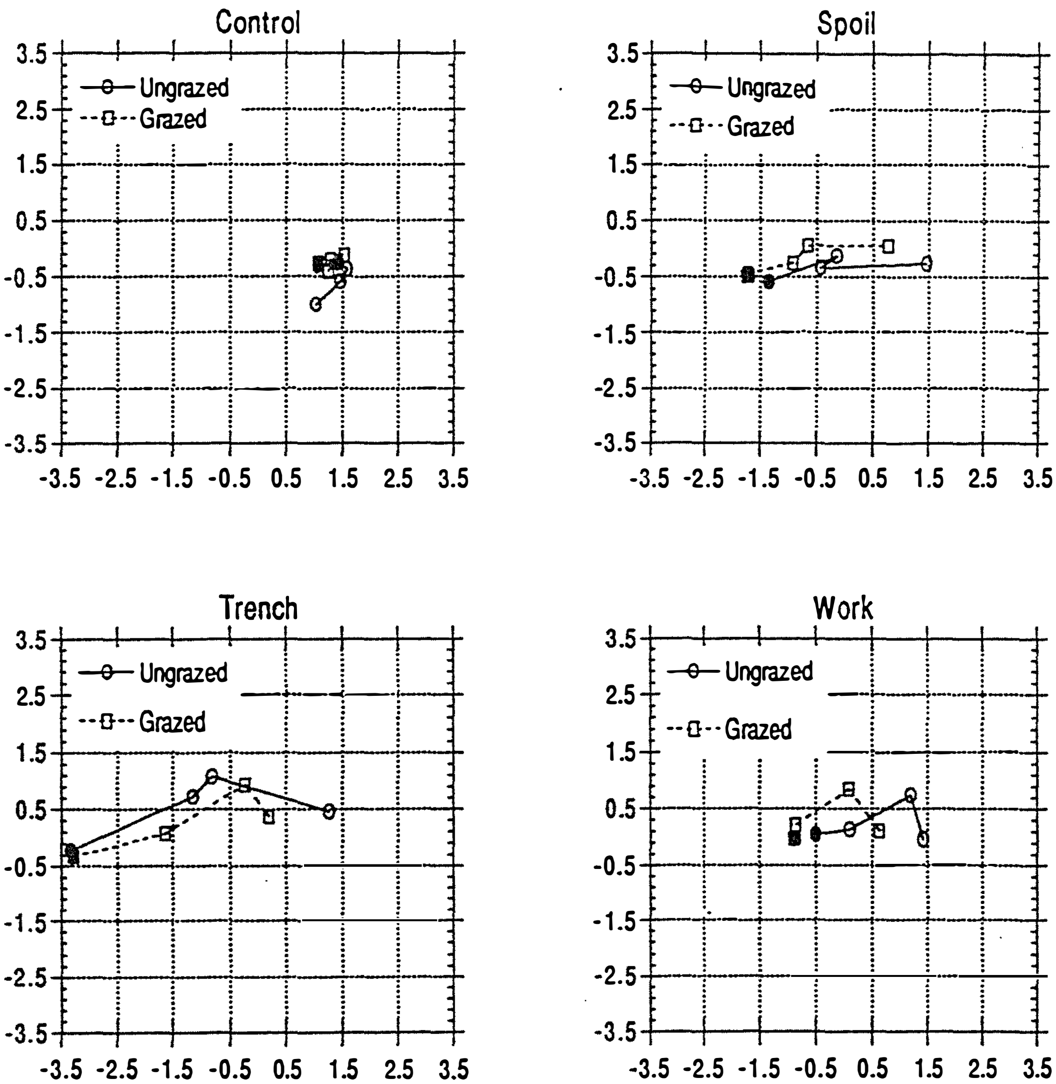


Figure 10. Graphical representation of dissimilarity matrices of cover data for the Porcupine Hills sites; bare ground and litter cover are included. Begin at the shaded symbol, which represents the 1988 data, and follow either the dashed or solid line.

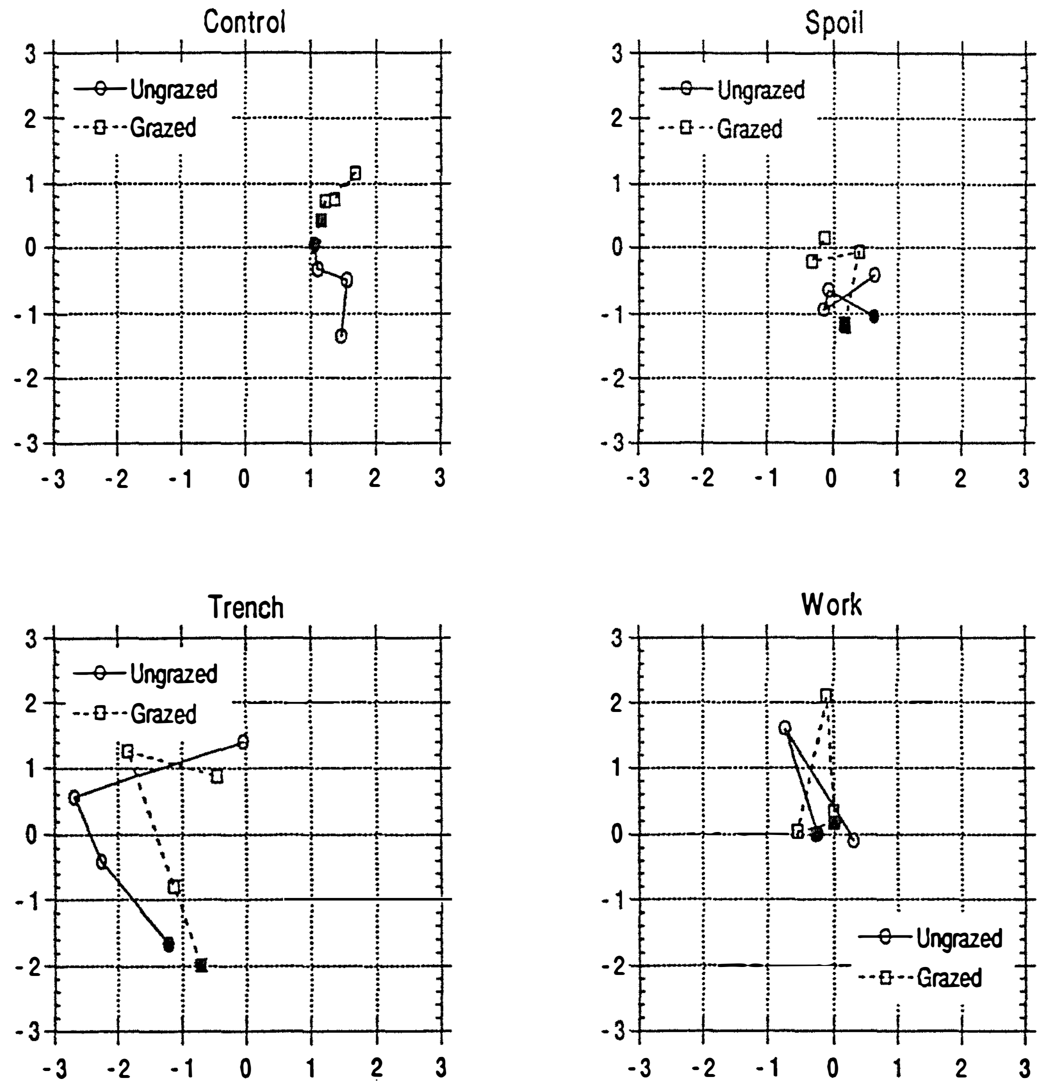


Figure 11. Graphical representation of dissimilarity matrices of cover data for the Porcupine Hills sites; bare ground and litter cover are excluded. Begin at the shaded symbol, which represents the 1988 data, and follow either the dashed or solid line.

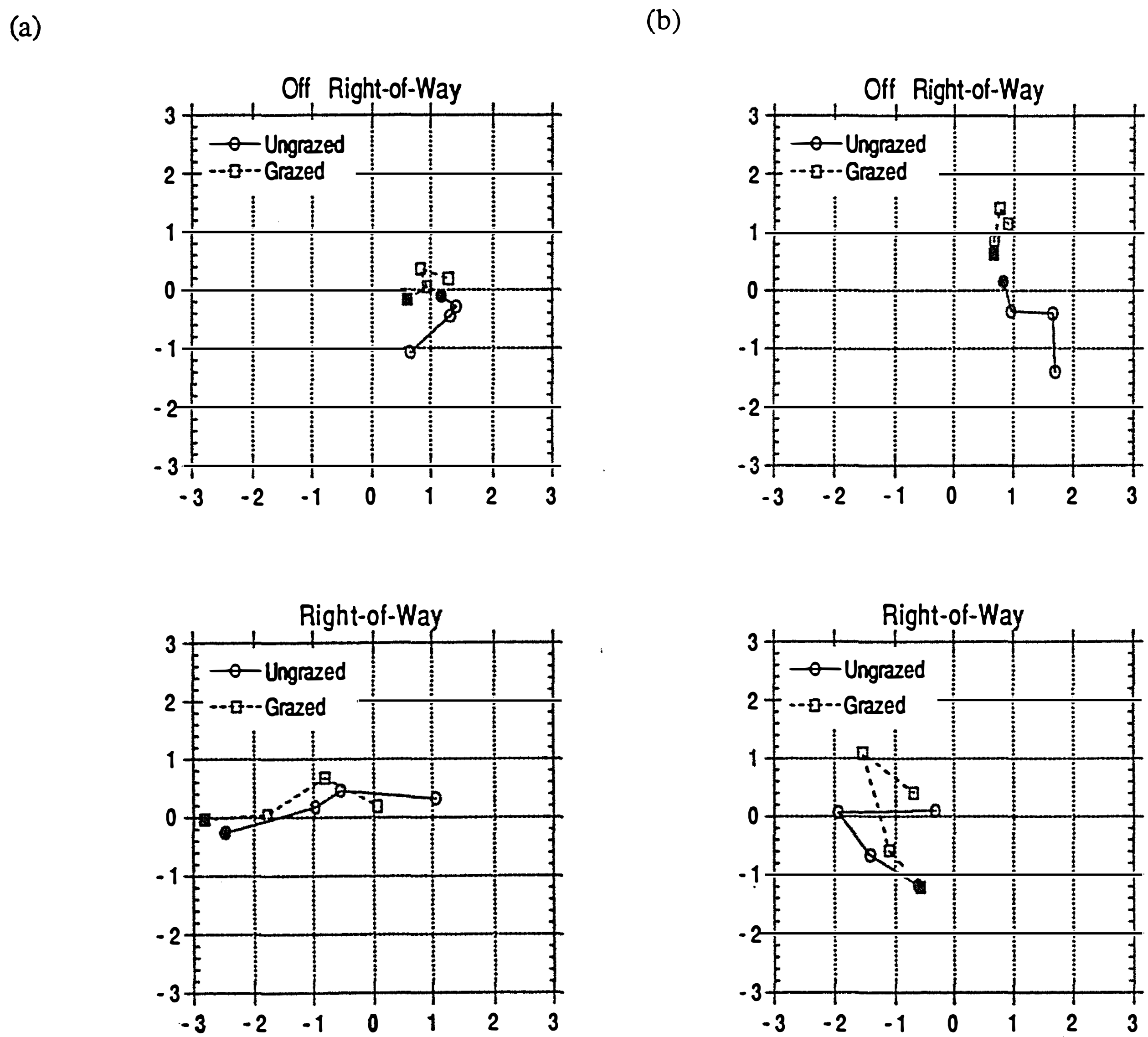


Figure 12. Graphical representation of dissimilarity matrices of cover data for Porcupine Hills sites; bare ground and litter cover are (a) included and (b) excluded. Begin at the shaded symbol, representing the 1988 data, and follow either the dashed or solid line.

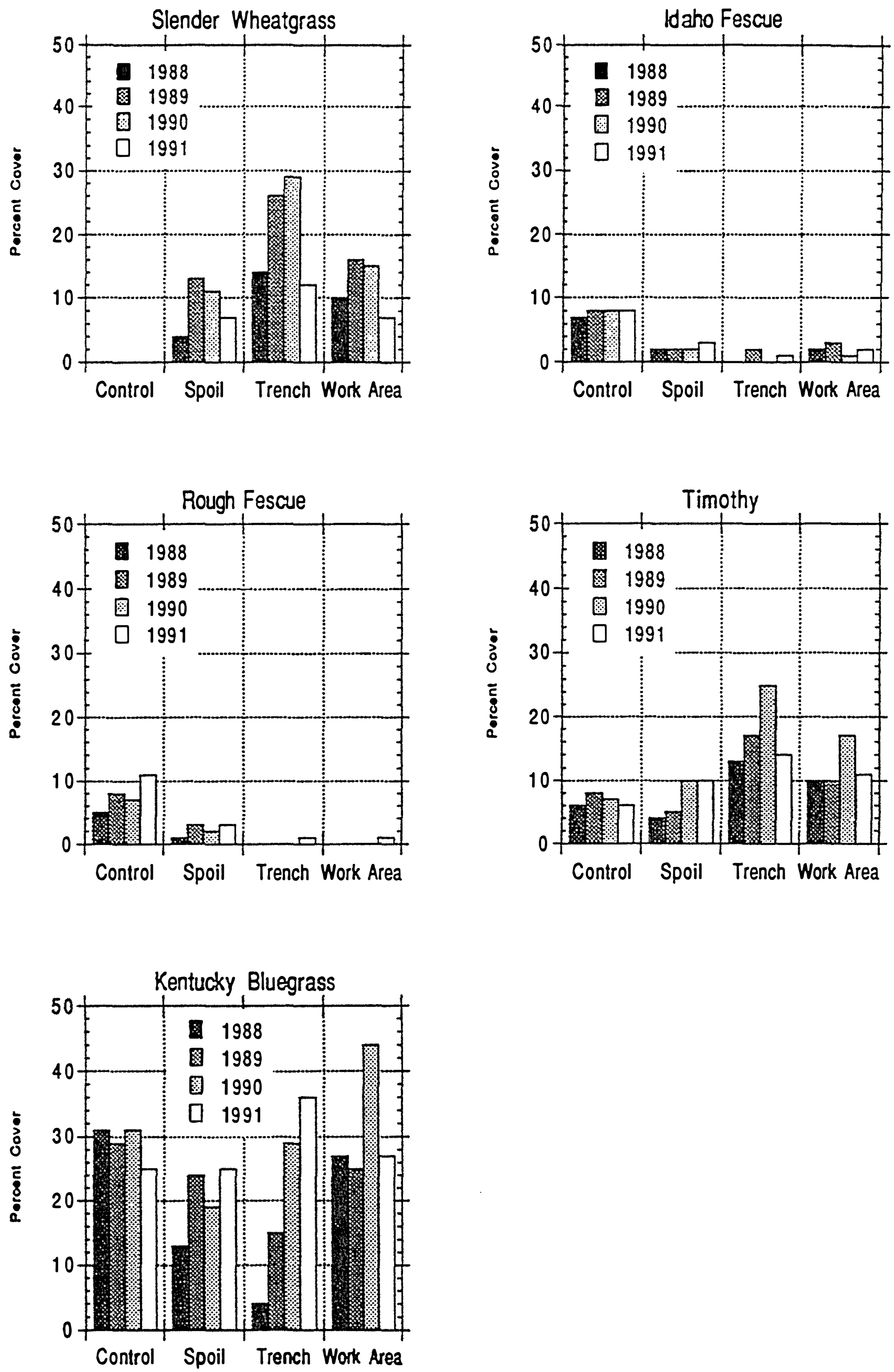


Figure 13. Percent cover of dominant species by year and treatment at the Porcupine Hills sites.

Table 7. Percent cover of bare ground and litter for main effects and two way interactions for the Porcupine Hills sites.

	Control			Spoil			Trench			Work			Year Mean	
Bare Ground														
1988	9	d	x	50	b	x	67	a	w	38	c	y	41	x
1989	7	b	x	38	a	y	48	a	x	40	a	x	33	xy
1990	9	c	x	35	a	y	34	a	y	21	b	z	25	y
1991	5	a	x	11	a	z	17	a	z	16	a	z	12	z
Treatment Mean	7	b		34	a		41	a		29	a			
Litter														
1988	80	a	x	34	b	y	5	c	y	49	a	y	42	z
1989	85	a	x	55	b	xy	43	b	x	61	ab	xy	61	y
1990	81	a	x	55	a	xy	56	a	x	73	a	xy	66	y
1991	77	a	x	82	a	x	73	a	x	83	a	x	79	x
Treatment Mean	81	a		57	bc		44	c		67	b			

Means in the same category (ie. bare ground, litter), for each column (xyz) and row (abc) that have the same letter, are not significantly different ($P < 0.05$).

fescue and rough fescue. The tendency for disturbed areas to be more similar to the control over time can be explained by the increase in Kentucky bluegrass on the spoil and trench over time.

Cover on grazed and ungrazed controls were less similar with time (Figure 11), due to declines in timothy and Kentucky bluegrass in ungrazed controls, while cover was constant in grazed controls. Native species remained constant in grazed and ungrazed treatments, or, as for rough fescue, increased uniformly in both treatments (Figure 13). On disturbed areas (trench, spoil, work area), grazing had little effect on cover. Where Kentucky bluegrass was dominant or co-dominant (Cyr, Davies, Rowland) in the control, cover was depressed initially by disturbance, but quickly re-established predisturbance levels and was not affected by grazing. Where it was not dominant or co-dominant on the control (Waldron), it was introduced with disturbance and became dominant but was inhibited by grazing. The ratio of non-native to total cover off-RoW and on trench was higher if grazed than ungrazed; on the spoil and work areas it was similar with treatment (Figure 14). This ratio was not plotted for Milo sites since introduced species cover values were very low.

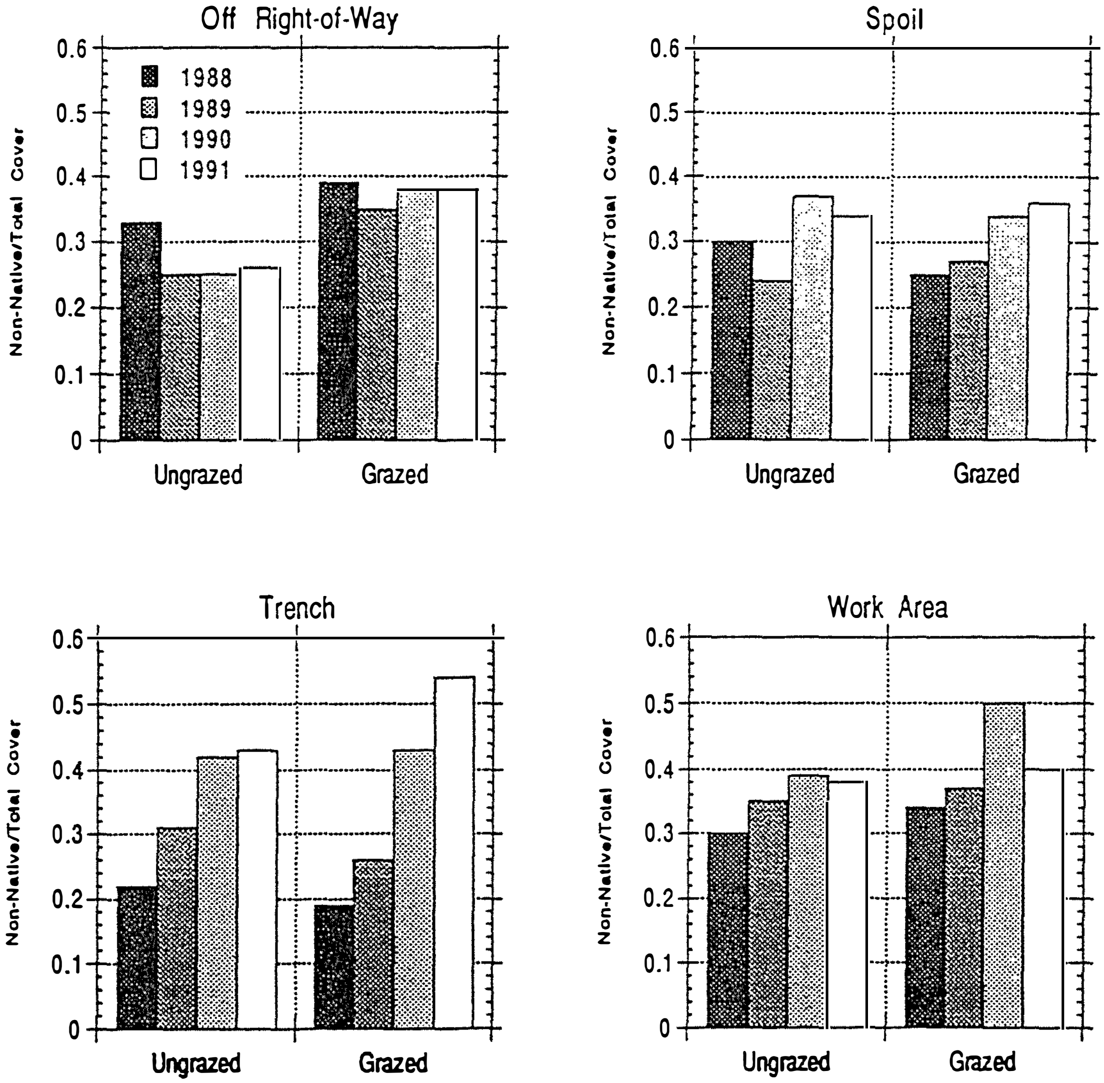


Figure 14. Ratio of non-native versus total cover at the Porcupine Hills sites.

C. Utilization

There was no significant difference in utilization between the trench and control at either the Milo or Porcupine Hills sites (Table 8). Trends were strong for higher utilization on the trench at both sites, but high variability limited significance. Grass utilization was consistent across years for both sites; forb utilization was not. Negative utilization may result from inherent variability in local vegetation, the inside/outside utilization method and random cage placement. These factors give higher grazed than ungrazed estimates and negative utilization values. Inconsistent forb utilization may lead to inconsistent total herbaceous utilization as well.

D. Seeded Versus Unseeded Treatments

Seeding versus no seeding had an effect on production, cover and individual species cover. Grass production was higher in the unseeded areas, forb production was higher in the seeded areas (with the exception of 1989), and total herbaceous production was higher in the unseeded areas in all three years (Table 9). Grass production increased steadily with time in both seeded and unseeded areas. Forbs and total herbaceous production increased by 1990 and then decreased by 1991. This is likely due to the increase in pioneer forb species in the early stages of succession after disturbance. More forbs would be expected initially in unseeded areas, where there is less competition from seeded grasses. However, the larger production values of grasses in the unseeded areas is difficult to explain.

Percent cover of total vegetation and litter increased with time from 1988 to 1991 in both the seeded and unseeded areas, whereas bare ground decreased during this time period (Figure 15). By 1991, total vegetation and litter cover was higher and bare ground was lower in the unseeded areas than in the seeded areas.

Individual species cover was also affected by seeding versus no seeding (Figure 16); only species with greater than 5% cover were assessed. Western wheatgrass cover was higher in the unseeded than the seeded areas. Northern wheatgrass cover was higher in the seeded areas than in the unseeded areas. Pasture sage decreased by 1991 in the seeded areas but increased in the unseeded areas; spear leaved goosefoot followed the opposite trend. Scarlet mallow was slightly higher in seeded areas than in unseeded areas. Buckbrush was only present in the unseeded areas, accounting for the larger forb production values in this area. Thus the seeded areas were dominated by northern wheatgrass and pasture sage; the unseeded areas were dominated by western wheatgrass and pasture sage.

Table 8. Grass, forb and total herbaceous percent utilization for main effects and two way interactions for the Milo and Porcupine Hills sites.

Milo	Control		Trench		Year Mean	
Grass						
1989	44		59		51	x
1990	33		64		48	x
1991	47		51		49	x
Treatment Mean	41	a	58	a		
Forb						
1989	33		39		36	x
1990	-15		45		15	x
1991	29		16		22	x
Treatment Mean	16	a	33	a		
Total Herbaceous						
1989	42		43		42	x
1990	29		51		40	x
1991	46		31		39	x
Treatment Mean	39	a	42	a		

Porcupine Hills	Control		Trench		Year Mean	
Grass						
1988	39		81		60	x
1989	54		90		70	x
1990	12		50		31	x
1991	42		70		56	x
Treatment Mean	37	a	72	a		
Forb						
1988	43		70		56	x
1989	39		42		40	x
1990	26		-9		8	y
1991	46		63		54	x
Treatment Mean	38	a	41	a		
Total Herbaceous						
1988	39		73		56	x
1989	50		58		54	x
1990	16		27		21	x
1991	42		67		54	x
Treatment Mean	37	a	56	a		

Means in the same category (ie. grass, forb, total herbaceous), for each column (xyz) and row (abc) that have the same letter, are not significantly different ($P < 0.05$).

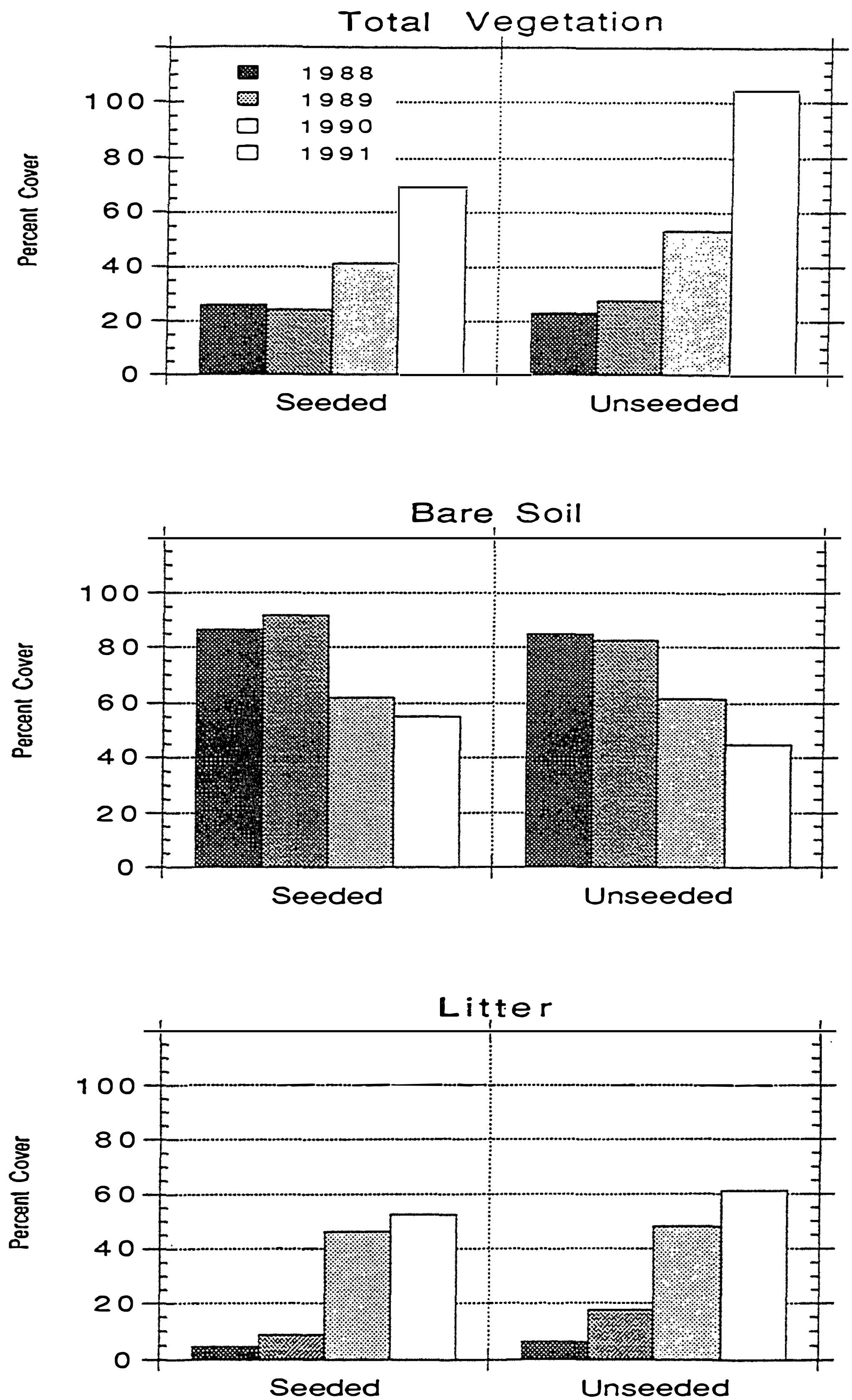


Figure 15. Percent cover of total vegetation, litter and bare ground in seeded and unseeded areas at Milo Site 4.

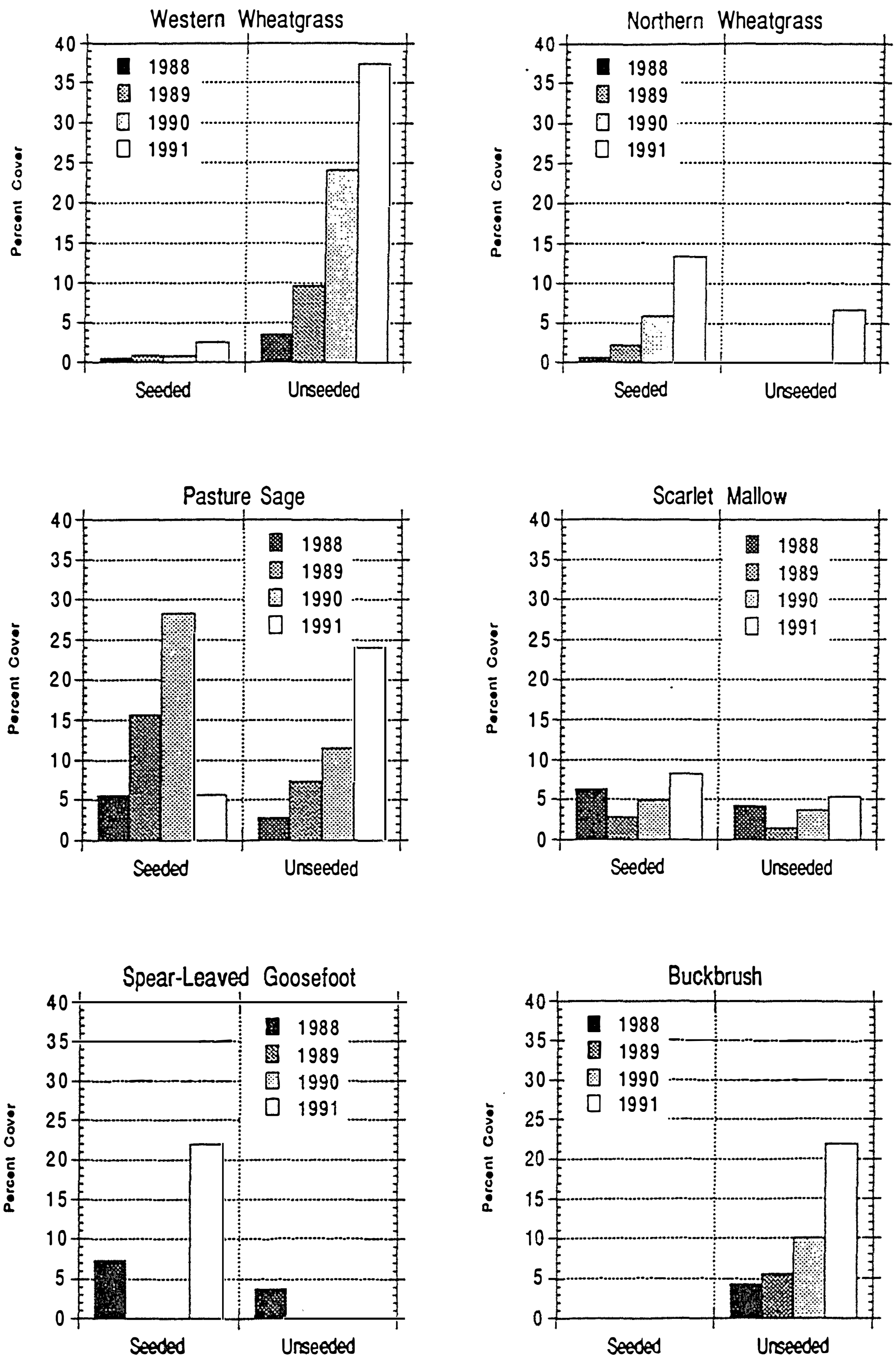


Figure 16. Percent cover of individual species in seeded and unseeded areas at Milo Site 4.

Table 9. Total grass, forb and herbaceous production (kg ha^{-1}) for main effects and two way interaction at Milo Site 4.

	Seeded		Unseeded		Year Mean	
Grass						
1989	50	a x	230	a y	140	y
1990	250	b x	1410	a x	830	x
1991	560	b x	2110	a x	1340	x
Treatment Mean	290	b	1250	a		
Forb						
1989	490		1100		800	y
1990	2190		1240		1710	x
1991	400		190		300	y
Treatment Mean	1030	a	840	a		
Total Herbaceous						
1989	550		1330		940	y
1990	2430		2650		2540	x
1991	960		2300		1630	y
Treatment Mean	1310	b	2090	a		

Means in the same category (ie. grass, forb, total herbaceous), for each column (xyz) and row (abc) that have the same letter, are not significantly different ($P < 0.05$).

V. SUMMARY AND CONCLUSIONS

Pipeline construction and subsequent reclamation affected vegetation production:

1. Grass production decreased within the first year following disturbance as was expected; as time progressed grass production increased and, at the Milo sites, often exceeded predisturbance levels.
2. Forb production increased within the first year following the disturbance; forb production on disturbed treatments generally remained higher than that on the control as time progressed.
3. Total herbaceous production generally increased with time on all disturbed treatments at the Milo sites, despite significant decreases with time in the undisturbed areas; the trend was similar but less striking at the Porcupine Hills sites, perhaps due to the more consistent precipitation. These total herbaceous production increases were due to increased grass production.
4. Changes in total production were most dramatic on the spoil treatment.
5. Grass production was higher on unseeded areas than on seeded areas.

Pipeline construction and subsequent reclamation affected site ground cover:

1. Bare ground increased immediately after disturbance as expected, then decreased after two years relative to the control. Within four years, there were no significant differences between disturbed areas seeded to native species and undisturbed controls. This trend was similar to areas seeded with non-native species, but bare ground was still significantly higher in disturbed areas compared to undisturbed areas at the end of four years.
2. Litter decreased after disturbance then increased within three years. After four years, in areas seeded to native species, litter on the trench was higher than that in the control. In areas seeded with non-native species, litter was higher in all disturbed treatments than in the control.
3. At the Milo sites, species composition of disturbed areas generally moved further away from predisturbed conditions with time. This was most notable for the areas seeded to non-native species. Those areas seeded to native species became more stable with time. Much of this dissimilarity was due to the lack of little club moss on the disturbed sites. Needle and thread grass tended to decrease the most on the spoil and trench. Pasture sage was greater on the disturbed treatments than on the control, but within four years was decreasing. Northern and western wheatgrasses tended to increase with time in disturbed areas seeded to native species, explaining the major differences in the disturbed and undisturbed areas.
4. At the Porcupine Hills sites, cover on disturbed areas moved towards undisturbed conditions within four years. Dissimilarities were explained by increases in Kentucky bluegrass on disturbed areas, even after four years.
5. There was no discernible effect of grazing on cover. When Kentucky bluegrass was dominant or co-dominant in undisturbed areas, grazing did not affect its re-establishment. Where it was not a dominant or co-dominant prior to disturbance, it tended to become dominant with disturbance. Only at the Waldron site, was Kentucky bluegrass establishment inhibited by grazing.

Pipeline construction and subsequent reclamation affected utilization:

1. There were strong but highly variable trends for higher overall utilization on the trench than in undisturbed areas at all sites.
2. Grass utilization was consistent across sites, forb utilization was not, likely due to the unpalatable nature of some of the forbs.

VI. BIBLIOGRAPHY

Can-Ag Enterprises Ltd. 1988. Porcupine Hills Lateral revegetation test plot soil inventory. Prepared for NOVA an Alberta Corporation.

Can-Ag Enterprises Ltd. 1988. Milo Lateral revegetation test plot soil inventory. Prepared for NOVA Corporation of Alberta.

Eastern Slopes Rangelands Consultants. 1987. Milo proposal revegetation research data report. Prepared for NOVA Corporation of Alberta.

Eastern Slopes Rangelands Consultants. 1988. Milo proposal revegetation research data report. Prepared for NOVA Corporation of Alberta.

Eastern Slopes Rangelands Consultants. 1989. Milo proposal revegetation research data report. Prepared for NOVA Corporation of Alberta.

Eastern Slopes Rangelands Consultants. 1990. Milo proposal revegetation research data report. Prepared for NOVA Corporation of Alberta.

Eastern Slopes Rangelands Consultants. 1991. Milo proposal revegetation research data report. Prepared for NOVA Corporation of Alberta.

Eastern Slopes Rangelands Consultants. 1987. Vegetation study on the Porcupine Hills Line. Prepared for NOVA Corporation of Alberta.

Eastern Slopes Rangelands Consultants. 1988. Vegetation study on the Porcupine Hills Line. Prepared for NOVA Corporation of Alberta.

Eastern Slopes Rangelands Consultants. 1989. Vegetation study on the Porcupine Hills Line. Prepared for NOVA Corporation of Alberta.

Eastern Slopes Rangelands Consultants. 1990. Vegetation study on the Porcupine Hills Line. Prepared for NOVA Corporation of Alberta.

Eastern Slopes Rangelands Consultants. 1991. Vegetation study on the Porcupine Hills Line. Prepared for NOVA Corporation of Alberta.

Steel, R. G. D. and J. H. Torrie. 1980. Principles and procedures of statistics. McGraw Hill Book Co., New York.

Strong, W. L. 1992. Ecoregions and ecodistricts of Alberta. Volume 1. Prepared for Alberta Forestry, Lands and Wildlife. Land Information Services Division. Resource Information Branch.

VII. APPENDICES

Appendix I: Species List For The Study Sites

A. Milo Sites

Site	Scientific Name	Common Name
1	*Agropyron albicans*	Wheatgrass
1	*Agropyron dasystachyum*	Northern wheatgrass
1	*Agropyron pectiniforme*	Crested wheatgrass
1	*Agropyron smithii*	Western wheatgrass
1	*Agropyron subsecundum*	Awned wheatgrass
1	*Agropyron trachycaulum*	Slender wheatgrass
1	*Bouteloua gracilis*	Blue grama
1	*Calamagrostis montanensis*	Reed grass
1	*Elymus junceus*	Wild rye
1	*Hordeum jubatum*	Foxtail barley
1	*Koeleria macrantha*	June grass
1	*Muhlenbergia richardsonis*	Mat muhly
1	*Poa canbyi*	Canby bluegrass
1	*Poa compressa*	Canada bluegrass
1	*Poa sandbergii*	Sandberg bluegrass
1	*Stipa comata*	Needle and thread
1	*Stipa curtiseta*	Western porcupine grass
1	*Stipa viridula*	Green needlegrass
1	*Carex obtusata*	Sedge
1	*Carex pensylvanica*	Sedge
1	*Carex sp.*	Sedge
1	*Carex stenophylla*	Sedge
1	*Achillea millefolium*	Yarrow
1	*Amaranthus albus*	Tumbleweed
1	*Androsace septentrionalis*	Fairy candelabra
1	*Antennaria aprica*	Pussy toes
1	*Antennaria parvifolia*	Pussy toes
1	*Arnica sp.*	Arnica
1	*Artemisia cana*	Sagebrush
1	*Artemisia frigida*	Pasture sage
1	*Artemisia ludoviciana*	Prairie sagewort
1	*Aster ericoides*	Tufted white prairie aster
1	*Aster falcatus*	Creeping white prairie aster
1	*Aster sp.*	Aster
1	*Astragalus sp.*	Milk vetch
1	*Betula glandulosa*	Bog dwarf birch
1	*Chenopodium album*	Lamb's quarters

1	*Comandra umbellata*	Bastard toadflax
1	*Descurainia sophia*	Tansy mustard
1	*Erysimum inconspicuum*	Small flowered rocket
1	*Eurotia lanata*	Winter fat
1	*Gaura coccinea*	Scarlet butterfly weed
1	*Grindella squarrosa*	Gum weed
1	*Gutierrezia sarothrae*	Broom snakeweed
1	*Heterotheca villosa*	Hairy golden aster
1	*Lappula occidentalis*	Blue burr
1	*Lappula squarrosa*	Blue burr
1	*Medicago sativa*	Alfalfa
1	*Monolepis nuttalliana*	Spear-leaved goosefoot
1	*Opuntia fragilis*	Prickly pear cactus
1	*Penstemon procerus*	Slender blue beard-tongue
1	*Phlox hoodii*	Hood's phlox
1	*Polygonum arenastrum (aviculare)*	Common knotweed
1	*Potentilla hippiana*	Cinquefoil
1	*Salsola kali*	Russian thistle
1	*Selaginella densa*	Little club moss
1	*Sisymbrium altissimum*	Tumbling mustard
1	*Solanum triflorum*	Wild tomato
1	*Solidago missouriensis*	Missouri goldenrod
1	*Solidago spathulata*	Goldenrod
1	*Sphaeralcea coccinea*	Scarlet mallow
1	*Symphoricarpos albus*	Buckbrush
1	*Taraxacum officinale*	Common dandelion
1	*Thalictrum venulosum*	Veiny meadow rue
1	*Thermopsis rhombifolia*	Golden bean
2	*Agropyron albicans*	Wheatgrass
2	*Agropyron dasystachyum*	Northern wheatgrass
2	*Agropyron pectiniforme*	Crested wheatgrass
2	*Agropyron smithii*	Western wheatgrass
2	*Agropyron trachycaulum*	Slender wheatgrass
2	*Bouteloua gracilis*	Blue grama
2	*Calamagrostis montanensis*	Reed grass
2	*Elymus junceus*	Wild rye
2	*Hordeum jubatum*	Foxtail barley
2	*Koeleria macrantha*	June grass
2	*Muhlenbergia richardsonis*	Mat muhly
2	*Poa canbyi*	Canby bluegrass
2	*Poa jucifolia*	Alkali bluegrass
2	*Poa sandbergii*	Sandberg bluegrass
2	*Puccinellia nuttalliana*	Nuttall's alkali grass
2	*Schedonnardus paniculatus*	Tumble grass
2	*Stipa comata*	Needle and thread

2	*Stipa viridula*	Green needlegrass
2	*Carex obtusata*	Sedge
2	*Carex pensylvanica*	Sedge
2	*Carex sp.*	Sedge
2	*Carex stenophylla*	Sedge
2	*Achillea millefolium*	Yarrow
2	*Allium cernumm*	Nodding onion
2	*Amaranthus albus*	Tumbleweed
2	*Androsace septentrionalis*	Fairy candelabra
2	*Antennaria aprica*	Pussy toes
2	*Antennaria parvifolia*	Pussy toes
2	*Artemisia campestris*	Sage
2	*Artemisia cana*	Sagebrush
2	*Artemisia frigida*	Pasture sage
2	*Artemisia ludoviciana*	Prairie sagewort
2	*Aster falcatus*	Creeping white prairie aster
2	*Aster sp.*	Aster
2	*Astragalus cicer*	Cicer mild vetch
2	*Astragalus sp.*	Milk vetch
2	*Atriplex nuttallii*	Salt sage
2	*Campanula rotundifolia*	Hair bluebell
2	*Chenopodium album*	Lamb's quarters
2	*Coryphantha vivipara*	Ball cactus
2	*Descurainia sophia*	Tansy mustard
2	*Erysimum inconspicuum*	Small flowered rocket
2	*Gaura coccinea*	Scarlet butterfly weed
2	*Grindella squarrosa*	Gum weed
2	*Gutierrezia sarothrae*	Broom snakeweed
2	*Hackelia sp.*	Stick seed
2	*Lappula occidentalis*	Blue burr
2	*Lappula squarrosa*	Blue burr
2	*Lepidium sp.*	Peppergrass
2	*Medicago sativa*	Alfalfa
2	*Monolepis nuttalliana*	Spear-leaved goosefoot
2	*Opuntia fragilis*	Prickly pear cactus
2	*Penstemon sp.*	Beard-tongue
2	*Phlox hoodii*	Hood's phlox
2	*Plantago sp.*	Plantain
2	*Polygonum arenastrum (aviculare)*	Common knotweed
2	*Potentilla arguta*	White cinquefoil
2	*Potentilla hippiana*	Cinquefoil
2	*Potentilla pensylvanica*	Cinquefoil
2	*Salsola kali*	Russian thistle
2	*Selaginella densa*	Little club moss
2	*Sisymbrium altissimum*	Tumbling mustard
2	*Solanum triflorum*	Wild tomato

2	*Solidago missouriensis*	Missouri goldenrod
2	*Solidago spathulata*	Goldenrod
2	*Sphaeralcea coccinea*	Scarlet mallow
2	*Taraxacum officinale*	Common dandelion
2	*Thalictrum venulosum*	Veiny meadow rue
2	*Thermopsis rhombifolia*	Golden bean
2	*Zizia aptera*	Meadow parsnip
3	*Agropyron dasystachyum*	Northern wheatgrass
3	*Agropyron pectiniforme*	Crested wheatgrass
3	*Agropyron smithii*	Western wheatgrass
3	*Agropyron subsecundum*	Awned wheatgrass
3	*Agropyron trachycaulum*	Slender wheatgrass
3	*Bouteloua gracilis*	Blue grama
3	*Calamagrostis montanensis*	Reed grass
3	*Hordeum jubatum*	Foxtail barley
3	*Koeleria macrantha*	June grass
3	*Muhlenbergia richardsonis*	Mat muhly
3	*Poa canbyi*	Canby bluegrass
3	*Poa compressa*	Canada bluegrass
3	*Poa sandbergii*	Sandberg bluegrass
3	*Stipa comata*	Needle and thread
3	*Stipa curtiseta*	Western porcupine grass
3	*Stipa richardsonii*	Richardson needlegrass
3	*Stipa viridula*	Green needlegrass
3	*Carex obtusata*	Sedge
3	*Carex pensylvanica*	Sedge
3	*Carex sp.*	Sedge
3	*Carex stenophylla*	Sedge
3	*Achillea millefolium*	Yarrow
3	*Androsace septentrionalis*	Fairy candelabra
3	*Anemone patens*	Prairie crocus
3	*Antennaria parvifolia*	Pussy toes
3	*Artemisia frigida*	Pasture sage
3	*Artemisia ludoviciana*	Prairie sagewort
3	*Aster ericoides*	Tufted white prairie aster
3	*Aster falcatus*	Creeping white prairie aster
3	*Astragalus cicer*	Cicer mild vetch
3	*Astragalus sp.*	Milk vetch
3	*Chenopodium album*	Lamb's quarters
3	*Cirsium arvense*	Canada thistle
3	*Cirsium flodmanni*	Flodman's thistle
3	*Cirsium undulatum*	Thistle
3	*Comandra umbellata*	Bastard toadflax
3	*Coryphantha vivipara*	Ball cactus
3	*Descurainia sophia*	Tansy mustard

3	*Elaeagnus commutata*	Silver berry
3	*Erysimum inconspicuum*	Small flowered rocket
3	*Gaillardia aristata*	Gaillardia
3	*Gaura coccinea*	Scarlet butterfly weed
3	*Grindella squarrosa*	Gum weed
3	*Haplopappus spinulosus*	Haplopappus
3	*Heterotheca villosa*	Hairy golden aster
3	*Lappula occidentalis*	Blue burr
3	*Lappula squarrosa*	Blue burr
3	*Lepidium sp.*	Peppergrass
3	*Liatris punctata*	Blazing star
3	*Lygodesmia juncea*	Skeleton weed
3	*Medicago sativa*	Alfalfa
3	*Melilotus sp.*	Sweet clover
3	*Minuartia rubella*	Sandwort
3	*Orthocarpus luteus*	Owl clover
3	*Phlox hoodii*	Hood's phlox
3	*Polygonum arenastrum (aviculare)*	Common knotweed
3	*Polygonum douglasii*	Knotweed
3	*Potentilla gracilis*	Graceful cinquefoil
3	*Rosa arkansana*	Prairie rose
3	*Salsola kali*	Russian thistle
3	*Selaginella densa*	Little club moss
3	*Sisymbrium altissimum*	Tumbling mustard
3	*Solidago missouriensis*	Missouri goldenrod
3	*Solidago sp.*	Goldenrod
3	*Sphaeralcea coccinea*	Scarlet mallow
3	*Thalictrum venulosum*	Veiny meadow rue
3	*Thermopsis rhombifolia*	Golden bean
3	*Vicia sparsifolia*	Wild vetch
3	*Zigadenus venenosus*	Death camas
4	*Agropyron dasystachyum*	Northern wheatgrass
4	*Agropyron glaucum*	Wheatgrass
4	*Agropyron smithii*	Western wheatgrass
4	*Agropyron trachycaulum*	Slender wheatgrass
4	*Agrostis scabra*	Hairgrass
4	*Bouteloua gracilis*	Blue grama
4	*Calamagrostis montanensis*	Reed grass
4	*Helictotrichon hookeri*	Hooker's oat grass
4	*Hordeum jubatum*	Foxtail barley
4	*Koeleria macrantha*	June grass
4	*Muhlenbergia richardsonis*	Mat muhly
4	*Poa sandbergii*	Sandberg bluegrass
4	*Poa sp.*	Bluegrass
4	*Stipa comata*	Needle and thread

4	*Stipa curtiseta*	Western porcupine grass
4	*Stipa viridula*	Green needlegrass
4	*Carex pennsylvanica*	Sedge
4	*Carex sp.*	Sedge
4	*Carex stenophylla*	Sedge
4	*Achillea millefolium*	Yarrow
4	*Amaranthus albus*	Tumbleweed
4	*Androsace septentrionalis*	Fairy candelabra
4	*Anemone patens*	Prairie crocus
4	*Antennaria parvifolia*	Pussy toes
4	*Artemisia frigida*	Pasture sage
4	*Artemisia ludoviciana*	Prairie sagewort
4	*Aster falcatus*	Creeping white prairie aster
4	*Astragalus pectinatus*	Narrow-leafed milk vetch
4	*Astragalus sp.*	Milk vetch
4	*Chenopodium album*	Lamb's quarters
4	*Descurainia sophia*	Tansy mustard
4	*Eurotia lanata*	Winter fat
4	*Gaura coccinea*	Scarlet butterfly weed
4	*Haplopappus spinulosus*	Haplopappus
4	*Heterotheca villosa*	Hairy golden aster
4	*Liatris punctata*	Blazing star
4	*Lygodesmia juncea*	Skeleton weed
4	*Monolepis nuttalliana*	Spear-leaved goosefoot
4	*Phlox hoodii*	Hood's phlox
4	*Polygonum arenastrum (aviculare)*	Common knotweed
4	*Polygonum sp.*	Knotweed
4	*Potentilla pensylvanica*	Cinquefoil
4	*Rosa arkansana*	Prairie rose
4	*Salsola kali*	Russian thistle
4	*Selaginella densa*	Little club moss
4	*Solanum triflorum*	Wild tomato
4	*Solidago missouriensis*	Missouri goldenrod
4	*Sonchus sp.*	Sow thistle
4	*Sphaeralcea coccinea*	Scarlet mallow
4	*Symphoricarpos occidentalis*	Buckbrush
4	*Thalictrum venulosum*	Veiny meadow rue
4	*Thermopsis rhombifolia*	Golden bean
4	*Vicia americana*	Wild vetch
4	*Vicia sparsifolia*	Wild vetch
4	*Viola sp.*	Early blue velvet

B. Porcupine Hills Sites

Site	Scientific Name	Common Name
Cyr	*Agropyron dasystachyum*	Northern wheatgrass
Cyr	*Agropyron glaucum*	Wheatgrass
Cyr	*Agropyron smithii*	Western wheatgrass
Cyr	*Agropyron subsecundum*	Awned wheatgrass
Cyr	*Agropyron trachycaulum*	Slender wheatgrass
Cyr	*Agrostis scabra*	Hairgrass
Cyr	*Bromus carinatus*	Mountain brome
Cyr	*Bromus inermis*	Smooth brome
Cyr	*Bromus pumpellianus*	Northern awnless brome
Cyr	*Calamagrostis montanensis*	Reed grass
Cyr	*Danthonia californica*	Oat grass
Cyr	*Danthonia parryi*	Parry oat grass
Cyr	*Festuca idahoensis*	Bluebunch fescue
Cyr	*Festuca rubra*	Creeping red fescue
Cyr	*Festuca scabrella*	Rough fescue
Cyr	*Helictotrichon hookeri*	Hooker's oat grass
Cyr	*Hierochloe odorata*	Sweetgrass
Cyr	*Hordeum jubatum*	Foxtail barley
Cyr	*Koeleria macrantha*	June grass
Cyr	*Phleum pratense*	Timothy
Cyr	*Poa alpina*	Alpine blue grass
Cyr	*Poa canbyi*	Canby bluegrass
Cyr	*Poa compressa*	Canada bluegrass
Cyr	*Poa cusickii*	Cusick bluegrass
Cyr	*Poa interior*	Wood bluegrass
Cyr	*Poa pratensis*	Kentucky bluegrass
Cyr	*Stipa columbiana*	Columbian needlegrass
Cyr	*Stipa curtiseta*	Western porcupine grass
Cyr	*Stipa viridula*	Green needlegrass
Cyr	*Carex praticola*	Sedge
Cyr	*Carex rossii*	Sedge
Cyr	*Carex siccata*	Sedge
Cyr	*Carex atrosquama*	Sedge
Cyr	*Carex obtusata*	Sedge
Cyr	*Carex pensylvanica*	Sedge
Cyr	*Carex scirpoidea*	Sedge
Cyr	*Carex stenophylla*	Sedge
Cyr	*Juncus balticus*	Wire rush
Cyr	*Achillea millefolium*	Yarrow
Cyr	*Allium cernuum*	Nodding onion
Cyr	*Androsace septentrionalis*	Fairy candelabra

Cyr	*Anemone multifida*	Cut-leaved anemone
Cyr	*Anemone patens*	Prairie crocus
Cyr	*Antennaria aprica*	Pussy toes
Cyr	*Antennaria parvifolia*	Pussy toes
Cyr	*Antennaria rosea*	Pussy toes
Cyr	*Aster laevis*	Smooth aster
Cyr	*Atriplex nuttallii*	Salt sage
Cyr	*Campanula rotundifolia*	Hair bluebell
Cyr	*Cerastium arvense*	Mouse-ear chickweed
Cyr	*Cirsium arvense*	Canada thistle
Cyr	*Comandra umbellata*	Bastard toadflax
Cyr	*Erigeron caespitosus*	Fleabane
Cyr	*Fragaria virginiana*	Wild strawberry
Cyr	*Gaillardia aristata*	Gaillardia
Cyr	*Galium boreale*	Northern bedstraw
Cyr	*Gentianella amarella*	Felwort
Cyr	*Geranium richardsonii*	Wild geranium
Cyr	*Geranium viscosissimum*	Sticky purple geranium
Cyr	*Hedysarum alpinum*	Northern sweet broom
Cyr	*Hedysarum sulphurescens*	Yellow sweetbroom
Cyr	*Lappula occidentalis*	Blue burr
Cyr	*Lithospermum ruderale*	Puccoon
Cyr	*Lomatium triternatum*	Prairie parsley
Cyr	*Lupinus sericeus*	Perennial lupine
Cyr	*Monolepis nuttalliana*	Spear-leaved goosefoot
Cyr	*Oxytropis monticola*	Late yellow locoweed
Cyr	*Penstemon confertus*	Yellow beard-tongue
Cyr	*Penstemon sp.*	Beard-tongue
Cyr	*Polygonum arenastrum (aviculare)*	Common knotweed
Cyr	*Polygonum bistortoides*	Bistort
Cyr	*Potentilla arguta*	White cinquefoil
Cyr	*Potentilla fruticosa*	Shrubby cinquefoil
Cyr	*Potentilla gracilis*	Graceful cinquefoil
Cyr	*Potentilla norvegica*	Cinquefoil
Cyr	*Ranunculus cardiophyllus*	Heart-leaved buttercup
Cyr	*Rosa acicularis*	Prickly rose
Cyr	*Rosa arkansana*	Prairie rose
Cyr	*Rosa sp.*	Rose
Cyr	*Rumex triangulivalis*	Narrow-leaved dock
Cyr	*Selaginella densa*	Little club moss
Cyr	*Senecio pauperculus*	Ragwort
Cyr	*Senecio sp.*	Ragwort
Cyr	*Sisyrinchium montanum*	Blue-eyed grass
Cyr	*Smilacina stellata*	Star-flowered Solomon's-seal
Cyr	*Solanum triflorum*	Wild tomato

Cyr	*Solidago missouriensis*	Missouri goldenrod
Cyr	*Solidago spathulata*	Goldenrod
Cyr	*Solidago sp.*	Goldenrod
Cyr	*Taraxacum officinale*	Common dandelion
Cyr	*Thalictrum venulosum*	Veiny meadow rue
Cyr	*Thermopsis rhombifolia*	Golden bean
Cyr	*Thlaspi arvense*	Stinkweed
Cyr	*Trifolium repens*	White Dutch clover
Cyr	*Vicia americana*	Wild vetch
Davies	*Agropyron dasystachyum*	Northern wheatgrass
Davies	*Agropyron glaucum*	Wheatgrass
Davies	*Agropyron subsecundum*	Awned wheatgrass
Davies	*Agropyron trachycaulum*	Slender wheatgrass
Davies	*Bromus carinatus*	Mountain brome
Davies	*Bromus inermis*	Smooth brome
Davies	*Bromus pumpellianus*	Northern awnless brome
Davies	*Dactyllis glomerata*	Orchard grass
Davies	*Danthonia californica*	Oat grass
Davies	*Festuca idahoensis*	Bluebunch fescue
Davies	*Festuca rubra*	Creeping red fescue
Davies	*Festuca scabrella*	Rough fescue
Davies	*Hordeum jubatum*	Foxtail barley
Davies	*Koeleria macrantha*	June grass
Davies	*Muhlenbergia richardsonis*	Mat muhly
Davies	*Phleum pratense*	Timothy
Davies	*Poa compressa*	Canada bluegrass
Davies	*Poa interior*	Wood bluegrass
Davies	*Poa jucifolia*	Alkali bluegrass
Davies	*Poa pratensis*	Kentucky bluegrass
Davies	*Stipa comata*	Needle and thread
Davies	*Carex atrosquama*	Sedge
Davies	*Carex eleocharis*	Sedge
Davies	*Carex pensylvanica*	Sedge
Davies	*Carex rossii*	Sedge
Davies	*Carex scirpoidea*	Sedge
Davies	*Carex siccata*	Sedge
Davies	*Carex stenophylla*	Sedge
Davies	*Juncus balticus*	Wire rush
Davies	*Achillea millefolium*	Yarrow
Davies	*Agoseris glauca*	False dandelion
Davies	*Androsace septentrionalis*	Fairy candelabra
Davies	*Aquilegia sp.*	Columbine
Davies	*Arabis drummondii*	Rock cress
Davies	*Aster laevis*	Smooth aster

Davies	*Aster sp.*	Aster
Davies	*Astragalus cicer*	Cicer mild vetch
Davies	*Campanula rotundifolia*	Hair bluebell
Davies	*Capsella bursa-pastoris*	Shepherd's purse
Davies	*Cerastium arvense*	Mouse-ear chickweed
Davies	*Chenopodium album*	Lamb's quarters
Davies	*Cirsium arvense*	Canada thistle
Davies	*Descurainia sophia*	Tansy mustard
Davies	*Fragaria virginiana*	Wild strawberry
Davies	*Galium boreale*	Northern bedstraw
Davies	*Geranium richardsonii*	Geranium
Davies	*Geranium viscosissimum*	Sticky purple geranium
Davies	*Geum aleppicum*	Yellow avens
Davies	*Geum macrophyllum*	Yellow avens
Davies	*Geum triflorum*	Three-flowered avens
Davies	*Lathyrus ochroleucus*	Pea vine
Davies	*Lomatium triternatum*	Prairie parsley
Davies	*Medicago lupulina*	Black medic
Davies	*Medicago sativa*	Alfalfa
Davies	*Penstemon confertus*	Yellow beard-tongue
Davies	*Perideridia gairdneri*	Squaw root
Davies	*Polygonum arenastrum (aviculare)*	Common knotweed
Davies	*Potentilla fruticosa*	Shrubby cinquefoil
Davies	*Potentilla gracilis*	Graceful cinquefoil
Davies	*Potentilla norvegica*	Cinquefoil
Davies	*Potentilla pensylvanica*	Cinquefoil
Davies	*Potentilla rivularis*	Cinquefoil
Davies	*Rosa acicularis*	Prickly rose
Davies	*Rosa arkansana*	Prairie rose
Davies	*Rosa woodsii*	Common wild rose
Davies	*Rubus idaeus*	Wild red raspberry
Davies	*Silene pratensis*	White cockle
Davies	*Sisyrinchium montanum*	Blue-eyed grass
Davies	*Taraxacum officinale*	Common dandelion
Davies	*Thalictrum venulosum*	Veiny meadow rue
Davies	*Thlaspi arvense*	Stinkweed
Davies	*Trifolium hybridum*	Alsike clover
Davies	*Trifolium repens*	White Dutch clover
Davies	*Vicia americana*	Wild vetch
Davies	*Viola adunca*	Early blue velvet
Rowland	*Agropyron dasystachyum*	Northern wheatgrass
Rowland	*Agropyron glaucum*	Wheatgrass
Rowland	*Agropyron smithii*	Western wheatgrass
Rowland	*Agropyron subsecundum*	Awned wheatgrass

Rowland	*Agropyron trachycaulum*	Slender wheatgrass
Rowland	*Bromus inermis*	Smooth brome
Rowland	*Bromus pumpellianus*	Northern awnless brome
Rowland	*Calamagrostis montanensis*	Reed grass
Rowland	*Danthonia parryi*	Parry oat grass
Rowland	*Festuca idahoensis*	Bluebunch fescue
Rowland	*Festuca rubra*	Creeping red fescue
Rowland	*Festuca saximontana*	Sheep fescue
Rowland	*Festuca scabrella*	Rough fescue
Rowland	*Helictotrichon hookeri*	Hooker's oat grass
Rowland	*Hordeum jubatum*	Foxtail barley
Rowland	*Koeleria macrantha*	June grass
Rowland	*Muhlenbergia richardsonis*	Mat muhly
Rowland	*Phleum pratense*	Timothy
Rowland	*Poa compressa*	Canada bluegrass
Rowland	*Poa interior*	Wood bluegrass
Rowland	*Poa pratensis*	Kentucky bluegrass
Rowland	*Poa sp.*	Bluegrass
Rowland	*Stipa columbiana*	Columbian needlegrass
Rowland	*Stipa curtiseta*	Western porcupine grass
Rowland	*Stipa richardsonii*	Richardson needlegrass
Rowland	*Stipa viridula*	Green needlegrass
Rowland	*Carex obtusata*	Sedge
Rowland	*Carex pensylvanica*	Sedge
Rowland	*Carex scirpoidea*	Sedge
Rowland	*Carex siccata*	Sedge
Rowland	*Carex stenophylla*	Sedge
Rowland	*Achillea millefolium*	Yarrow
Rowland	*Agoseris glauca*	False dandelion
Rowland	*Allium cernumm*	Nodding onion
Rowland	*Androsace septentrionalis*	Fairy candelabra
Rowland	*Anemone cylindrica*	Long-fruited anemone
Rowland	*Anemone multifida*	Cut-leaved anemone
Rowland	*Anemone patens*	Prairie crocus
Rowland	*Antennaria neglecta*	Pussy-toes
Rowland	*Antennaria nitida (parvifolia)*	Pussy toes
Rowland	*Antennaria parvifolia*	Pussy toes
Rowland	*Antennaria rosea*	Pussy toes
Rowland	*Arctostaphylos uva-ursi*	Common bearberry
Rowland	*Artemisia frigida*	Pasture sage
Rowland	*Aster laevis*	Smooth aster
Rowland	*Astragalus cicer*	Cicer mild vetch
Rowland	*Astragalus sp.*	Milk vetch
Rowland	*Campanula rotundifolia*	Hair bluebell
Rowland	*Capsella bursa-pastoris*	Shepherd's purse

Rowland	*Cerastium arvense*	Mouse-ear chickweed
Rowland	*Chenopodium album*	Lamb's quarters
Rowland	*Cirsium arvense*	Canada thistle
Rowland	*Cirsium flodmanni*	Flodman's thistle
Rowland	*Comandra umbellata*	Bastard toadflax
Rowland	*Cynoglossum officinale*	Hound's tongue
Rowland	*Descurainia sophia*	Tansy mustard
Rowland	*Erigeron glabellus*	Fleabane
Rowland	*Erysimum inconspicuum*	Small flowered rocket
Rowland	*Fragaria virginiana*	Wild strawberry
Rowland	*Gaillardia aristata*	Gaillardia
Rowland	*Galium boreale*	Northern bedstraw
Rowland	*Gentianella amarella*	Felwort
Rowland	*Geum triflorum*	Three-flowered avens
Rowland	*Hackelia americana*	Stick-seed
Rowland	*Hedysarum alpinum*	Northern sweetbroom
Rowland	*Heuchera spp.*	Alum root
Rowland	*Juniperus horizontalis*	Creeping juniper
Rowland	*Lappula occidentalis*	Blue burr
Rowland	*Lappula squarrosa*	Blue burr
Rowland	*Lathyrus ochroleucus*	Pea vine
Rowland	*Linum lewisii*	Wild blue flax
Rowland	*Lithospermum ruderale*	Puccoon
Rowland	*Monarda fistulosa*	Horse mint
Rowland	*Monolepis nuttalliana*	Spear-leaved goosefoot
Rowland	*Oxytropis deflexa*	Reflexed locoweed
Rowland	*Oxytropis monticola*	Late yellow locoweed
Rowland	*Oxytropis splendens*	Showy locoweed
Rowland	*Polygonum arenastrum (aviculare)*	Common knotweed
Rowland	*Populus tremuloides*	Trembling aspen
Rowland	*Potentilla arguta*	White cinquefoil
Rowland	*Potentilla fruticosa*	Shrubby cinquefoil
Rowland	*Potentilla hippiana*	Cinquefoil
Rowland	*Potentilla pensylvanica*	Cinquefoil
Rowland	*Potentilla rivularis*	Cinquefoil
Rowland	*Rosa acicularis*	Prickly rose
Rowland	*Rosa arkansana*	Prairie rose
Rowland	*Salix pseudomonticola*	Willow
Rowland	*Salix sp.*	Willow
Rowland	*Selaginella densa*	Little club moss
Rowland	*Senecio canus*	Prairie groundsel
Rowland	*Shepherdia canadensis*	Canadian buffalo berry
Rowland	*Sisyrinchium montanum*	Blue-eyed grass
Rowland	*Smilacina stellata*	Star-flowered Solomon's seal
Rowland	*Soncus sp.*	Sow thistle

Rowland	*Taraxacum officinale*	Common dandelion
Rowland	*Thalictrum venulosum*	Veiny meadow rue
Rowland	*Thermopsis rhombifolia*	Golden bean
Rowland	*Trifolium repens*	White Dutch clover
Rowland	*Vicia americana*	Wild vetch
Rowland	*Vicia sparsifolia*	Wild vetch
Rowland	*Viola adunca*	Early blue velvet
Rowland	*Viola sp.*	Early blue velvet
Rowland	*Zigadenus elegans*	White camus
Rowland	*Zizia aptera*	Meadow parsnip
Rowland	*Zizia aptera*	Meadow parsnip
Waldron	*Agropyron albicans*	Wheatgrass
Waldron	*Agropyron dasystachyum*	Northern wheatgrass
Waldron	*Agropyron glaucum*	Wheatgrass
Waldron	*Agropyron pectiniforme*	Crested wheatgrass
Waldron	*Agropyron smithii*	Western wheatgrass
Waldron	*Agropyron subsecundum*	Awned wheatgrass
Waldron	*Agropyron trachycaulum*	Slender wheatgrass
Waldron	*Agrostis scabra*	Hairgrass
Waldron	*Bromus inermis*	Smooth brome
Waldron	*Bromus pumpellianus*	Northern awnless brome
Waldron	*Bouteloua gracilis*	Blue grama
Waldron	*Calamagrostis montanensis*	Reed grass
Waldron	*Festuca idahoensis*	Bluebunch fescue
Waldron	*Festuca rubra*	Creeping red fescue
Waldron	*Festuca saximontana*	Sheep fescue
Waldron	*Festuca scabrella*	Rough fescue
Waldron	*Helictotrichon hookeri*	Hooker's oat grass
Waldron	*Hordeum jubatum*	Foxtail barley
Waldron	*Koeleria macrantha*	June grass
Waldron	*Muhlenbergia richardsonis*	Mat muhly
Waldron	*Poa canbyi*	Canby bluegrass
Waldron	*Poa compressa*	Canada bluegrass
Waldron	*Poa cusickii*	Cusick bluegrass
Waldron	*Poa pratensis*	Kentucky bluegrass
Waldron	*Poa sandbergii*	Sandberg bluegrass
Waldron	*Stipa curtiseta*	Western porcupine grass
Waldron	*Stipa viridula*	Green needlegrass
Waldron	*Carex filifolia*	Sedge
Waldron	*Carex obtusata*	Sedge
Waldron	*Carex pensylvanica*	Sedge
Waldron	*Carex scirpoidea*	Sedge
Waldron	*Carex stenophylla*	Sedge
Waldron	*Achillea millefolium*	Yarrow

Waldron	*Allium cernumm*	Nodding onion
Waldron	*Amaranthus albus*	Tumbleweed
Waldron	*Androsace septentrionalis*	Fairy candelabra
Waldron	*Anemone cylindrica*	Long-fruited anemone
Waldron	*Anemone multifida*	Cut-leaved anemone
Waldron	*Anemone patens*	Prairie crocus
Waldron	*Antennaria aprica*	Pussy toes
Waldron	*Antennaria neglecta*	Pussy toes
Waldron	*Antennaria parvifolia*	Pussy toes
Waldron	*Antennaria rosea*	Pussy toes
Waldron	*Arnica sp.*	Arnica
Waldron	*Artemisia cana*	Sagebrush
Waldron	*Artemisia frigida*	Pasture sage
Waldron	*Artemisia ludoviciana*	Prairie sagewort
Waldron	*Aster ericoides*	Tufted white prairie aster
Waldron	*Aster falcatus*	Creeping white prairie aster
Waldron	*Aster sp.*	Aster
Waldron	*Astragalus flexuosus*	Milk vetch
Waldron	*Cirsium arvense*	Canada thistle
Waldron	*Cirsium flodmanni*	Flodman's thistle
Waldron	*Cirsium vulgare*	Bull thistle
Waldron	*Comandra umbellata*	Bastard toadflax
Waldron	*Cynoglossum officinale*	Hound's-tongue
Waldron	*Descurainia sophia*	Tansy mustard
Waldron	*Eleagnus commutata*	Silver-berry
Waldron	*Gaillardia aristata*	Gaillardia
Waldron	*Galium boreale*	Northern bedstraw
Waldron	*Gaura coccinea*	Scarlet butterfly weed
Waldron	*Gentianella amarella*	Felwort
Waldron	*Geum triflorum*	Three-flowered avens
Waldron	*Gutierrezia sarothrae*	Broom snake-weed
Waldron	*Haplopappus spinulosus*	Haplopappus
Waldron	*Heterotheca villosa*	Hairy golden aster
Waldron	*Lappula occidentalis*	Blue burr
Waldron	*Lappula squarrosa*	Blue burr
Waldron	*Lepidium sp.*	Peppergrass
Waldron	*Lithospermum ruderale*	Puccoon
Waldron	*Medicago sativa*	Alfalfa
Waldron	*Monolepis nuttalliana*	Spear-leaved goosefoot
Waldron	*Opuntia fragilis*	Prickly pear cactus
Waldron	*Oxytropis deflexa*	Reflexed locoweed
Waldron	*Oxytropis splendens*	Showy loco-weed
Waldron	*Penstemon nitidus*	Smooth blue beard-tongue
Waldron	*Phlox hoodii*	Hood's phlox
Waldron	*Polygonum arenastrum (aviculare)*	Common knotweed

Waldron	*Potentilla gracilis*	Graceful cinquefoil
Waldron	*Potentilla hippiana*	Cinquefoil
Waldron	*Potentilla pensylvanica*	Cinquefoil
Waldron	*Rosa acicularis*	Prickly rose
Waldron	*Rosa arkansana*	Prairie rose
Waldron	*Salsola kali*	Russian thistle
Waldron	*Selaginella densa*	Little club moss
Waldron	*Senecio canus*	Prairie groundsel
Waldron	*Sisymbrium altissimum*	Tumbling mustard
Waldron	*Sisyrinchium montanum*	Blue-eyed grass
Waldron	*Solanum triflorum*	Wild tomato
Waldron	*Solidago missouriensis*	Missouri goldenrod
Waldron	*Solidago sp.*	Goldenrod
Waldron	*Sphaeralcea coccinea*	Scarlet mallow
Waldron	*Symphoricarpos occidentalis*	Buckbrush
Waldron	*Taraxacum officinale*	Common dandelion
Waldron	*Vicia americana*	Wild vetch
Waldron	*Vicia sparsifolia*	Wild vetch
Waldron	*Viola sp.*	Early blue velvet
Waldron	*Zigadenus venenosus*	Death camas

Appendix II: Standard Errors And Significances For The Study Sites

Table 1. Grass, forb and total herbaceous production standard errors and significance levels for main effects and two way interactions for the Milo sites.

		Year	Treatment	Year By Treatment
Grass	Standard Error	130	170	120
	Significance	0.03	0.86	0.02
Forb	Standard Error	90	50	130
	Significance	0.82	0.00	0.01
Total	Standard Error	170	150	170
	Significance	0.09	0.09	0.00

Table 2. Grass, forb and total herbaceous production standard errors and significance levels for main effects and two way interactions for the Porcupine Hills sites.

		Year	Treatment	Year By Treatment
Grass	Standard Error	290	220	330
	Significance	0.08	0.21	0.72
Forb	Standard Error	140	190	190
	Significance	0.27	0.21	0.38
Total	Standard Error	260	240	290
	Significance	0.11	0.04	0.89

Table 3. Bare ground and litter cover standard errors and significance levels for main effects and two way interactions for Milo sites with the native seed mix.

		Year	Treatment	Year By Treatment
Bare Ground	Standard Error	3.5	5.6	5.3
	Significance	0.008	0.073	0.003
Litter	Standard Error	4.8	3.8	3.5
	Significance	0.089	0.489	0.000

Table 4. Bare ground and litter cover standard errors and significance levels for main effects and two way interactions for Milo sites with the non-native seed mix.

		Year	Treatment	Year By Treatment
Bare Ground	Standard Error	2.6	4.6	3.3
	Significance	0.052	0.016	0.000
Litter	Standard Error	3.8	5.5	3.6
	Significance	0.475	0.630	0.004

Table 5. Bare ground and litter cover standard errors and significance levels for main effects and two way interactions for the Porcupine Hills sites.

		Year	Treatment	Year By Treatment
Bare Ground	Standard Error	3.7	4.8	3.8
	Significance	0.002	0.004	0.000
Litter	Standard Error	3.6	4.4	8.3
	Significance	0.000	0.001	0.036

Table 6. Grass, forb and total herbaceous percent utilization standard errors and significance levels for main effects and two way interactions for Milo sites.

		Year	Treatment	Year By Treatment
Grass	Standard Error	5.0	2.0	2.0
	Significance	0.92	0.10	0.05
Forb	Standard Error	14.2	3.0	8.0
	Significance	0.63	0.13	0.07
Total	Standard Error	9.0	5.0	4.0
	Significance	0.96	0.76	0.08

Table 7. Grass, forb and total herbaceous percent utilization standard errors and significance levels for main effects and two way interactions for Porcupine Hills sites.

		Year	Treatment	Year By Treatment
Grass	Standard Error	8.0	8.0	10.0
	Significance	0.10	0.25	0.78
Forb	Standard Error	13.0	10.0	15.0
	Significance	0.05	0.23	0.09
Total	Standard Error	9.0	5.0	6.0
	Significance	0.06	0.23	0.34